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CONTENTS

The Application and Use of Botanical Names. *H. W. Rickett and W. H. Camp* 245

Inhibition of Growth and Cell Division in Onion Roots by Maleic Hydrazide ..... *Victor A. Greulach and Earlene Atchison* 262

Notes on Geocarpon minimum Mackenzie. *Ernest J. Palmer and Julian A. Steyermark* 268

The Developmental Morphology of the Mutant "Corn Grass." *W. Gordon Whaley and James H. Leech* 274

Control of Basal Rot of Cuttings of Chrysanthemum and Other Ornamentals ..... *C. M. Tompkins and John T. Middleton* 287

The Natural and Synthetic Quinones in Relation to the Functions of Plants ..... *George L. McNew* 294

A Giant New Codium from Pacific Baja California ..... *E. Yale Dawson* 298

Induced Vascular Differentiation ..... *F. B. Witkus and C. A. Berger* 301

Torreya 306

Obituary: Homer Doliver House. Field Trip Reports. Notes. Book Reviews.

Index to American Botanical Literature 312

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THE APPLICATION AND USE OF BOTANICAL NAMES

H. W. RICKETT AND W. H. CAMP

Introduction. One of the most significant advances in the history of nomenclature was made in 1904 when the type method was formally proposed. As is well known, this principle was advocated in the following year at the international botanical congress of Vienna, but ignored by the botanists there assembled. Although in constant use by many taxonomists it was not formally adopted and written into the rules until 1930, at the congress which met in Cambridge. In the third edition of the *International Rules of Botanical Nomenclature* (Camp et al. 1947), which resulted from that congress, Article 18 states that "The application of names of taxonomic groups is determined by means of *nomenclatural types.*" However, this tardy acceptance of the principle did not mean that all the implications of the type method had been fully realized or that all provisions of the rules had been brought into harmony with it. At the following congress, which met in Amsterdam in 1935, there was much tinkering with the rules. Words, phrases, and paragraphs were added, others deleted, new recommendations were inserted, new examples were furnished—until it requires considerable legal acumen to find one's way through the resulting patchwork of articles, recommendations, examples, and appendices. None of this, however, accomplished any real change in the spirit of the rules; the type method remained as a somewhat incompatible graft on the old body. Now, after a lapse of fifteen years, another congress impends, in preparation for which botanists all over the world have long been busy formulating new proposals for changes in and additions to the rules. This paper is being written and sent to the printer before the congress convenes; prediction is, of course, impossible, but we fear that the great mass of proposals just mentioned will lead to no thorough re-examination or recasting of the rules, but only to an additional effort to clarify or amplify minor points.

Even a casual reading of the present text makes it evident that the rules are based on "groups" and "circumscriptions" rather than on types. It is not our purpose here to search out all the articles, recommendations, phrases, and words in the third edition that exemplify our arguments; actual rewriting of the rules must await a more general acceptance of the basic principle—the type method. However, certain articles are outstanding in

their disharmony with this principle, and may be here briefly considered as an introduction to the main thesis of this paper.

One reads in Article 44, "The name of a species or of a subdivision of a species is not validly published unless it is accompanied (1) by a description *of the group;* or (2) by the citation of a previously and effectively published description *of the group. . . .*" (italic ours). If this article were ever to be enforced, there would be enough work to keep all our nomenclators busy for many years; for by this standard many species have not been validly published, having been named on the basis of *single individuals.* This is still a necessary practice in exploratory taxonomy; apparently modern authors are proceeding with the type method, ignoring Article 44 and its implications. But let us suppose that the contention may be dismissed as mere quibbling—obviously the framers of the rules did not intend that single collections should all be outlawed as bases of species; it is nevertheless true that the basis of the publication of a name is here envisaged as the *circumscription of a group* rather than the designation of a type.

Pursuit of conflicts between the rules and the type method brings us to a second example. Article 41, often invoked to invalidate names of genera, families, and higher groups, states that "a group is not characterized, and the publication of its name is not validated, merely by mention of the subordinate groups included in it. . . ." There are obviously two matters here. First, "a group is not characterized. . . ." On the face of it this is untrue; a group may be very well characterized by mention of the groups included in it; in fact, speaking philosophically, this is what characterization really means; but, in any case, what has *characterization* to do with nomenclature? Evidently for the writers of this rule the application of a name must be determined by a formal description, derived from a circumscription; their method was that of Linnaeus and his predecessors. Secondly, if there is one thing that is plain about the type method, it is that the application of a name *is* determined by the mention of a subordinate group; otherwise, why, in Article 18, should it be stated that "the type of the name of an order or suborder is a family, that of the name of a family, subfamily, tribe or subtribe is a genus, that of a generic name is a species. . . ."? Nomenclature is concerned with names and the means of applying them—not with the characterization of the groups to which they are to be applied. *A name is a means of reference, not a description* (cf. Art. 15).

Nomenclature and the Type Method. The principal thesis of this paper is that *botanical names are the names of types.* This was almost written "botanical names *should be* the names of types." But the statement would have been less than the truth. To the extent that the type method is actually in use, and to the extent that botanical names mean anything, the names

apply to the types, and *from the purely nomenclatural point of view, to the types only.*

This is obviously true of purely exploratory taxonomy. When it is impossible to match a specimen with anything known and named, it receives a name of its own; this specimen, of course, is the type of the new name. Even if a second specimen, of what seems the same taxon comes to light, and a third, the new name "belongs" to the original specimen; in the absence of adequate field study it is obviously dangerous to decide from such scanty material whether or not they are identical, and taxonomists generally are cautious in doing so. Examples are numerous and well known of presumed identities resolved into distinct taxa; the name by which they were temporarily known is the name of the original type, and of that specimen alone.

At this point the reader may object, with some reason, that the name, although applied first to the type, and inalienably associated with it by the rules of nomenclature (except in very unusual instances), actually belongs to a number of plants, a population in fact, of which the type is only a representative. The others are there waiting to furnish collections to be filed in museums, at which time the same name will apply to all of them. Is not this the only purpose of having a name at all?

We have stepped across an invisible boundary: the line between nomenclature and taxonomy. The words "from the purely nomenclatural point of view" were set in italic in a preceding paragraph to emphasize that this is primarily a paper on nomenclature. As soon as we make decisions on the identity of plants, we are making scientific judgments: we are taxonomists. Nomenclature is purely a matter of rules: there is no science in it. It may be taken as axiomatic that taxonomic judgments—or anything that even hints of them—must be excluded from rules of nomenclature.

Among the many redundancies of the current text of the rules is Article 16, which says that "Each group with a given *circumscription*, position and rank can bear only one valid name. . . ." (italic ours). In Article 50 we are further told that "an alteration of diagnostic characters, or of the *circumscription* of a group, does not warrant a change in its name" (except under certain special conditions); and in Article 47 that such alterations do not "warrant the citation of an author other than the one who first published its name." These three articles must be considered together: the aspect here examined is the "circumscription" of a group.

In 1753 Linnaeus founded the genus *Panicum*, with twenty species. Of these, *P. alopecuroides* and *P. glaucum* were later removed[1] to *Pennisetum; P. italicum* to *Setaria; P. crusgalli* to *Echinochloa; P. dissectum* to *Paspalum; P. dimidiatum* to *Stenotaphrum; P. sanguinale* and *P. filiforme* to

[1] The authority for these segregations is Hitchcock (1935, 1936); three species not listed by him are cited on the authority of the *Index kewensis.*

Digitaria; P. compositus to *Oplismenus; P. dactylon* to *Cynodon;* and *P. arborescens* to *Arundinaria. P. americanum* is unidentifiable. The remaining eight species are still in *Panicum.* Meanwhile hundreds of additional species have been discovered and added, not to the Linnaean genus with its hotch-potch of species, but to our modern idea of *Panicum;* Hitchcock listed 160 species from the United States alone. What has become of Linnaeus' genus? What has it to do with "our modern idea of *Panicum*"? There are eight species in common to the two concepts—a minority of those with which the genus was founded. The circumscription of the group has changed many times, and who would venture to assert that the present generic outlines will never again be disturbed? In fact the circumscription *must* change whenever a new species is described. Articles 47 and 50 have been repeatedly invoked to preserve the name and authority of *Panicum* unchanged; but they alone could not have succeeded in doing this through the constant shifting of taxonomic judgments. The only thing that we have been able to fix upon as common to the Linnaean and to the modern genus, *whatever remains to be discovered,* is not a "given circumscription," but the type.[2] All Linnaeus' species save this one may conceivably be removed from the genus *Panicum.* And what species shall be associated with it is purely a matter of taxonomic judgment and entirely outside nomenclature. The fact is that, *for nomenclature,* circumscription does not matter. *The name applies only to the type.*

Examples may easily be multiplied. *Euphorbia* by some has been divided into *Euphorbia, Chamaesyce, Poinsettia, Tithymalus, Tithymalopsis,* etc. By others all these are considered as subordinate groups within the one genus. This is a matter of taxonomic judgment. For nomenclature it matters only that *Euphorbia* is the generic name of the type, *E. antiquorum;* various species, or none, may be associated with this by taxonomists, with no change in the name of the genus. Except for this device the name *Euphorbia* might wander among the segregates at the choice of every new student of the group who might think that his own favorite segregate should carry the name. This sort of thing did indeed happen before the type method was adopted; the following is but one example.

In 1776 Johann Reinhold Forster and Johann Georg Adam Forster established the genus *Epacris,* with the three species *E. longifolia, E. juniperina,* and *E. pumila.* Cavanilles in 1797 named several species in this genus, but included in his treatment none of the original three. Robert Brown in 1810 transferred *E. juniperina* to *Cyathodes, E. pumila* to *Pentachondra,* and *E. longifolia* to *Dracocephalum,* "since the Forsterian species are hardly known to most botanists, and nearly all the Epacrides more recently described do not belong to the genus named in this work." The original genus thus should have disappeared into synonymy, since the type must have been one of the

[2] In this case, of course, a lectotype or "standard species": *P. miliaceum.*

original three species. Yet the name continues in use for the species "more recently described." Recognition of the illegality of this usage has prompted a proposal to conserve the name in the latter sense, the type to be *E. longiflora* Cav. (Camp et al. 1949, p. 48). This is simply a proposal to *change the type* of the name from one of the "Forsterian species" to one of Cavanilles' later additions; *the name of the genus applying only to the type.* The circumscription of the genus was altered almost in the beginning of its history, and may perhaps continue to vary with taxonomic opinion; but if the congress votes to establish *E. longiflora* as the type, the name of the genus is then fixed (it becomes, of course, *Epacris* Cav. instead of *Epacris* Forst.).

As with genera, so with species. *Erigeron foliosus* was founded by Nuttall in 1840. In the latest revision of this genus (Cronquist 1947), *E. foliosus* included *E. douglasii* T. & G., *E. stenophyllus* Nutt., *E. nuttallii* Heller, *E. setchellii* Jepson, *E. confinis* Howell, and nine of Greene's species of *Erigeron.* Subsequent research by another student, or by methods other than those of "classical" taxonomy, may possibly result in restoring some or all of these names to specific rank, or in their transfer to other species. Certainly each was thought by its founder to have a definite circumscription outside that of *E. foliosus* as he understood it. Since the plants which received these names were not known to Nuttall, it is probably impossible to say to what extent the circumscription of *E. foliosus* which he had in mind would have included them; certainly he did not include his own *E. stenophyllus* in it. The only means we have of attaching any permanent meaning to the name *E. foliosus* is to recognize that it is the name of a certain specimen named by Nuttall and preserved in the Academy of Natural Sciences of Philadelphia, and that it has no fundamental permanence as the name of a circumscribed taxon. (The other names likewise are the names of type specimens, whether or not it is deemed taxonomically sound to regard them as referring to distinct taxa.)

In the *Species plantarum* (1753, p. 535, 536), *Magnolia virginiana* included five varieties, *α glauca, β foetida, γ grisea, δ tripetala,* and *ε acuminata.* In the *Systema naturae* of 1759 (ed. 10, p. 1082) we find four species, *M. grandiflora, M. glauca, M. acuminata,* and *M. tripetala.* Three of these are the former varieties *foetida, acuminata,* and *tripetala,* while the remaining one is *M. virginiana* renamed *glauca,* shorn of its varieties and thus radically redefined. As its circumscription changes, *M. virginiana* retains its status as a specific name only because it is the name of something we can select as a type.[3]

It should be noted that, contrary to popular supposition, this was not

[3] In this case presumably one of the specimens in the Linnaean herbarium; in default of that, Catesby's plate cited by Linnaeus in synonymy.

Linnaeus' own concept of a name. The name of a certain species described in the *Species plantarum* was *Ranunculus foliis inferioribus palmatis, summis digitatis, fructibus oblongis.* The "nomen triviale," *sceleratus,* was added (on the margin of the page, and indexed *as a monomomial*) because it was often inconvenient to use the full name; also because the discovery of new species or other new data would probably necessitate revision of it.[4] Linnaeus was here ahead of his time. He clearly saw the difference between a description and a means of reference; while he chose to make the "name" descriptive, as all his contemporaries did, he recognized its inconvenience and offered a more artificial device as a substitute—a "single word, taken at random." The reception accorded this device must have surprised him. Everyone was using it in a short time. Binomials took the place of long descriptive names; the descriptions could easily be found when wanted.

Until recently, however, the description (or figure) remained the chief means of fixing the identity of a species. The type method came with full recognition of the inadequacy of a description to fix a nomenclatural point of reference. We may say, accordingly, that the type method is the final step in the realization that a scientific name is not a description but a means of reference. It is equally the final step in the establishment of the binomial system. The name may be meaningless in itself (what does *Galax aphylla* tell us about this certainly leafy plant? Or *Asclepias syriaca* about this native American species?); its only use is that it guides us to the type.

When we attempt to climb the nomenclatural ladder upwards from genera, we find divided counsels and some confusion. From their earliest recognition the "natural orders"—what we now call the "families"—were named quite loosely in either of two ways: by reference to genera which they contained and on which they were based; or by some outstanding characters through which they were recognized. So Adanson in 1763 wrote of "les Mirtes. Myrti," "Les Vervènes. Verbenae," and so on; also of "Les Composées. Compositae" and "Les Ombellifères. Umbellatae." De Jussieu in 1789 wrote "Umbelliferae," "Cruciferae," and "Corymbiformae," besides "Ericae," "Gentianae," and the rest. Lindley in 1836 introduced (but did not consistently apply) the principle of uniformity of termination for groups of the same rank; he fixed on the suffix "*-aceae*" for the names of all families (many of which already had this form). The international rules of nomenclature adopted in 1930 further prescribed that the names of families be

[4] "Nomina trivialia . . . constarent . . . vocabulo unico; vocabulo libere undequaque desumto. Ratione hac praecipue evicti, quod differentia saepe longa evadit, ut non ubique commode usurpentur, et dein mutationi obnoxia, novis detectis speciebus, est. . . ." (*Philosophia botanica,* p. 202). "Trivial names are composed of a single word; a word taken at random. For this reason especially we have shown them, that the long difference [polynomial] often escapes us, and is not everywhere conveniently used, and moreover subject to change, by newly discovered species. . . ."

"taken from one of their genera" (Art. 23). To bring this into final conformity with the type method it is necessary only to change it to read "taken from their *type genera.*"

There is also, in the present Article 23, a list of eight permissible exceptions to the rule. All but two of these are descriptive names; i.e., relics of times when names of families often signalized their outstanding characters. Such are Cruciferae, Leguminosae, Guttiferae, Umbelliferae, Labiatae, Compositae. In a rational and consistent system of nomenclature such exceptions should be eliminated; they are retained only as a concession to those who imagine that it is impossible to accustom oneself to new names for well known plants. (Yet how many would now favor a return to "Cryptogamae" for serious scientific purposes?) It is also beyond our comprehension that the use of pre-Linnaean (and therefore untypifiable) generic names or of long-discarded generic names is permitted in the formation of familial names, unless it be the persistent desire of taxonomists to avoid any real system in their systematics. It is time to bring our naming of families up to date; the means are at hand—and refreshingly simple.

As we mount higher to ever more refined atmospheres of phylogenetic speculation, it is natural—because of the loose system now employed—that the names used be less and less precise in their application, more and more the equivalents of purely descriptive terms. This is apparent in the names of orders. Recent synopses by Hutchinson (1926–1934) and by Diels (1936) include such names as Umbelliflorae, Leguminosae, Cruciales, Personales, Synanthae, Tubiflorae, Glumiflorae, Spathiflorae, Farinosae, and Principes, besides the more familiar Pandanales, Salicales, Geraniales, and the rest. There is no clue in the names of the former group to the families included. There is, for instance, no discoverable family Personaceae, nor a genus *Persona* for its type. Words like Tubiflorae and Synanthae might apply to many groups of plants—or, alternatively, designate wholly artificial assemblages of plants marked by a given character (e.g., tubular corolla). This is particularly unfortunate in dealing with orders, since they naturally fluctuate greatly in their limits—their circumscriptions—with taxonomic opinion. Hutchinson lists 105 orders of flowering plants; Diels arranges the same plants in 55 orders (we assume his "Reihe" to be an order). The five orders Personales, Lamiales, Solanales, Boraginales, and Polemoniales of Hutchinson's treatment correspond to the single order Tubiflorae of Diels'—or to the Polemoniales of Robinson and Fernald (1908). In these shifting alignments—which of course reflect differences in taxonomic judgment and are not matters of nomenclature—it is important that the names used have the same point of reference for everyone. In short, fixed names are the more essential as the circumscriptions of the taxa involved are less fixed.

If you have trouble with a descriptive name—"Contortae," for instance, —and doubt its applicability to the group you are treating, you may easily rename it by some—in your opinion—better character, to the ultimate confusion of your readers. Certainly such names *must* be changed with increases in knowledge. For example, if the Cornaceae are retained in the same order with the Umbelliferae (Ammiaceae) and Araliaceae, the name of the order must be changed from Umbellales to something more truly descriptive—for the Cornaceae have no umbels.

What Linnaeus wrote of his specific names is true also of names in general. *Descriptive names are subject to change through the discovery of new species*, and of new data of any kind. The principle of priority is of no help here, for one cannot determine the first descriptive name ever applied to an order without in some way defining—circumscribing—the order. Obviously the only way to achieve the desired stability of nomenclature is to abandon descriptive names and to typify each order by one of its included families (or by the genus on which this is based; the difference is purely verbal), and to prescribe that the name of an order be taken from its type family (or genus) with a suitable suffix. The Personales become, let us say, the Scrophulariales, and it is at once considerably more apparent to everyone just what is meant (since there is no genus *Persona* and no family Personaceae). No matter what segregations and recombinations are made among this group of orders (and they will certainly continue to be made), this name will always apply to the order containing the family Scrophulariaceae and the genus *Scrophularia*. The remaining problem—just which families shall be associated with this one to form the order—is taxonomy, not nomenclature. We cannot stabilize taxonomy in the sense of halting the march of new knowledge and new ideas; but we can stabilize the basic nomenclature which is—or should be—the handmaid of taxonomy.

Finally, when we reach the stratosphere of supraordinal names, there are no longer landmarks by which to steer. The view is obscured by the remains of old classifications, each with its impressive array of descriptive names. Acotyledones, Monocotyledones, Dicotyledones—these were but one attempt to arrange all plants in a natural system. The groups have persisted into more modern systems, but of course in different relationships with each other; and one of the names has been quite abandoned, doubtless as being insufficiently descriptive. Vasculares, Cellulares, Exogenae, Endogenae, Cormophyta, Tracheophyta, Strobiloideae, Calyciflorae, Amentiferae, Cotyloideae,—these and a host of others swarm in the darkling sky. At present the well known names Thallophyta, Bryophyta, Pteridophyta, Spermatophyta are dying a lingering death. Three of them no longer apply to groups which we can consider natural. As these portents wane, such names as Pteropsida, Lycopsida, Chlorophycophyta rise in the east—subject to the

same objections. They will have their day, will be written in all the books, and their ultimate passing will be as painful and as necessary as that of those which went before them.

Beyond the vague recommendation that "some similarity of form and termination [be] given to those which designate groups of the same nature," there is no guide in the current international rules to the making of names for higher categories. Before a logical nomenclature can be established, it would seem necessary to regulate the form of the names to indicate their rank, as is now done (more or less) with families and orders. Further than this, we can make names which characterize the groups, or we can introduce the type method. Let us take the first alternative, and let us suppose, for the sake of the argument, that we are agreed at least about the main divisions of the plant kingdom: the bryophytes, the ferns, the lycopods, the conifers, the cycads, the flowering plants, and the others. How shall we proceed to the naming of these groups, save by such common names as those just employed, which have neither precision nor scientific significance? Is their vascular anatomy to be the basis of the name, or the presence of archegonia, or the intervention of a pollen tube? These are matters of viewpoint, even of taste; the systematist, the anatomist, the morphologist, the cytologist will have different ideas. If one is to use descriptive names, there are only two means of fixing them in position: to choose the prior one; or to conserve every name by special legislation. The first would result in the revival of absurdly outmoded names; the second would necessitate endless litigation; either would announce to the scientific world that taxonomists had no intention of constructing a nomenclatural system which could keep pace with scientific progress. The alternative to establishing fixed descriptive names is to do as we do now—use whatever names are dictated by individual preference, or happen to be in the treatment nearest at hand, perhaps with a prescribed ending as a novel feature.

Of course the troubles just adumbrated are greatly increased if—as is certainly the case—we do *not* all agree either about the limits of our groups or about their relationships. The remaining possibility is to carry the type method throughout the entire range of categories of classification. In the group of plants now known as the Angiospermae or flowering plants a type may be designated; let us say the Magnolia order (or, what amounts to the same thing, the genus *Magnolia*). The name of the group then becomes Magnolio + whatever prescribed suffix may be thought desirable. If the contention of a few modern students that the flowering plants are not monophyletic be generally adopted at some time in the future, that group which emerges in possession of the genus *Magnolia* would retain the name; it will be necessary only to pick a type for the segregated group, let us say the genus *Piper*, and construct its name accordingly. It must be kept clearly

in mind that *each name is the name of a type, regardless* of current ideas on its position in the scheme of things or its circumscription. This is merely to say that divisions and classes and the intermediate categories are taxa just as genera and species are taxa, and the same principles of nomenclature that are good for the latter are good also for the former.[5] For the purposes of nomenclature names are the names of types and of types alone; circumscription belongs to taxonomy.

Proposed Suffixes for the Higher Categories. The largest taxon of plants to receive a name authorized by the current international rules of nomenclature is the division; some botanists are using the word phylum apparently as a substitute. A division contains one or more classes, a class one or more orders. Intercalary categories such as subdivision, subclass may be inserted as needed. Names of all the above categories are at present the subject of Recommendation VIII: i.e., they are not fixed in any way by an article of the rules. The ending *-ales* for orders is recommended and more or less established by usage; the same is true of the ending *-ineae* for suborders. For taxa above the rank of order no recommendations are made save that the names be "words of Greek or Latin origin in the plural number." A proposal is to be laid before the Seventh International Botanical Congress[6] to make the endings of names of all categories mandatory. With this ideal the present writers are in agreement.

The exact form of the names would, at first glance, seem not to matter greatly, provided that they are reasonably easy to spell and pronounce and meet with general acceptance. However, arbitrary endings such as those hitherto in use for the most part have no meaning and constitute a source of confusion, especially in the minds of students venturing for the first time into taxonomy. Even experienced taxonomists must often pause to enquire whether a particular suffix refers to a subclass or a tribe.[7] The following scheme is therefore proposed to bring about clarity and to end confusion. It is self-explanatory and may be readily understood not only by professional botanists but also by others interested in plants. In fact, it will probably be opposed for no reason other than its simplicity and taxonomic clarity. Though only names above orders are in present need of legislation, we have, *for the sake of consistency and systematic order,* suggested carrying the

[5] It will be fairly obvious to the reader that the rules of nomenclature, rewritten in accord with the principle of the type method, would be far simpler than the present version, and occupy far less space.

[6] By a special committee appointed to consider the nomenclature of higher categories.

[7] In the proposal to be made by the committee mentioned in the preceding note, divisions are to be signalized by the suffix *-phyta,* while names of subdivisions end in *-phytea.* In the current text of the rules, suborders end in *-ineae,* subtribes in *-inae.* Such distinctions are too subtle to be easily detected in verbal communication (as in a lecture) and too liable to typographical error.

scheme downward from the division to the tribe—applying it to all names above those of genera. The scheme is to append to the names of the types not a series of purely arbitrary and mostly meaningless endings but syllables designating the rank of the categories. The division or phylum typified by *Magnolia* may be named the Magnoliophylum.[8] The class typified in the same way is the Magnolioclassis. And so on. The categories may be arranged in tabular form as follows.

Magnoliophylum
Magnolioclassis
Magnoliordo
Magnoliofamilia
Magnoliotribus
Magnolia
Magnolia virginiana.

The intercalation of intermediate categories is equally simple. If a subclass is to be designated, its name would be Magnoliosubclassis. Subfamilies, suborders, subtribes may all be named as they are needed, without a tax upon the imagination or the memory.

Although the designation of a system of suffixes is nomenclature, the application of such a system is of course taxonomy. The taxonomist must decide, for instance, whether all vascular plants are sufficiently closely related to be placed in one division (phylum), or whether the separate large taxa of vascular plants—ferns, lycopods, cycads, conifers, flowering plants, etc.—each constitute a division.

So the flowering plants, as a group, may vary in rank (and in the suffix applied to their name) with variation in taxonomic thought; they may, for example, be the Magnoliophylum, a division; or the Magnolioclassis, a class. In neither case need there be any doubt of the reference or application of the name; each applies to the genus *Magnolia*, together with such other genera—families—orders— classes—as taxonomists may choose to associate with it on the particular level indicated by its suffix. The one thing needful to establish such a nomenclatural hierarchy is the arbitrary selection of a type. The genus *Lilium*, for example, seems a fairly obvious choice for the type of the family and order to which it belongs (Liliofamilia, Liliordo); it

[8] In any case the suffix *-phyta*, though long in use, is to be avoided for the division or phylum. Certain groups of organisms now roughly classed as "algae" and dealt with by botanists are thought not to be "plants" under a strict application of the term; and certain mycologists now contend that the fungi are not really plants, since their protoplasts exhibit characteristically "animal" reactions. Those who wish to label groups of organisms as belonging to the plant kingdom should, to be consistent, devise a suffix for that purpose to be appended to the names of genera, since there are many homonyms among plant and animal genera. But this again is taxonomy; it is not the business of the nomenclator to determine where in the scheme of things the taxa which he designates should be placed, and his names should not imply any such judgments.

might be designated the type of the class of all so-called monocotyledonous plants, the Lilioclassis. But if the flowering plants as a whole are to be subordinated to the vascular plants, it might be desirable to name them as a class Magnolioclassis, with the "monocots" and "dicots" as subclasses—Liliosubclassis and Magnoliosubclassis. These are all taxonomic decisions, nothing is more certain than that they will vary again and again; but there is no need for any obscurity in the use of the names. Curiously enough, the type method when applied in this way to nomenclature results in a greater stability of names combined with extreme flexibility in the taxonomic use of names.

On Synonyms. A curious detail of nomenclature which has hitherto escaped careful scrutiny is the citation of synonyms. What is a synonym? The *Rules*, though they occasionally use the word, are silent on its meaning. The dictionary has several shades of meaning: synonyms are distinct words with the same meaning; or distinct names for the same thing; or, in biology, names "regarded as incorrectly applied, or as incorrect in form or spelling." In any modern systematic study, the accepted name of a genus or species or other taxon is commonly followed by a list of other, rejected names. Some of these, like the synonyms of *Erigeron foliosus* mentioned above, are names of what were thought to be distinct taxa now "reduced" to conspecificity. In the opinion of the systematist in question, there is but one taxon represented, and all names except the earliest are to be rejected as synonymous. The decision is taxonomic (one of circumscription), not nomenclatural, and, as has been already pointed out, not necessarily permanent. On the other hand, a synonym may be another name for the same type; there is no possibility that more than one can be legitimate, no matter what systematist reviews the taxon in question. These are nomenclatural synonyms. An example cited in the *Rules* is *Chrysophyllum sericeum* Salisb., a new name for *C. cainito* L. Many of the irrepressible Rafinesque's names for genera were new names chosen to displace older names merely because of his objections to the latter on linguistic grounds, without any change in type.

Such distinctions between kinds of synonyms may seem superfluous; but examination of certain modern practices shows how—without clear statement of the type method as applied to nomenclature—our synonymy may wallow in a slough of confusion. For instance, in a recent treatment of North American blueberries (Camp 1945), the name *Vaccinium alto-montanum* Ashe is followed by these synonyms: *Cyanococcus liparis* Small, *Vaccinium liparum* Uphof, *Cyanococcus subcordatus* Small, *Vaccinium subcordatum* Uphof, *Cyanococcus tallapusae* Coville, *Vaccinium tallapusae* Uphof. The names of each pair (e.g. *C. liparis, V. liparum*) are nomenclatural synonyms, based on one type; only one can correctly be used at any one time. But

whether *C. liparis* is or is not a synonym of *V. alto-montanum* is a matter of circumscription and depends upon taxonomic judgment. In short, this list of synonyms involves two very different kinds of statements about names. Another and more complex example may be found in a well-known and useful treatment of the genus *Ranunculus* (Benson 1948).[9] Here we find the description of a taxon headed *Ranunculus hispidus* var. *typicus,* nom. nov., and following this as synonyms the names *R. hispidus* Michx., *R. repens* L. var. *hispidus* Chapm., and *R. hirtipes* Greene. Of course the citation of the first synonym does not really mean what it might seem to, that the variety (*typicus*) is the same as the species which includes it and other varieties. The whole is still greater than the part, even in botany. It means only that the variety has the same type as the species. On the other hand, *R. hirtipes* is a name given to a taxon proposed as distinct but considered by this student to be included in the circumscription of *R. hispidus* var. *typicus;* it is a taxonomic, not a nomenclatural synonym. These two types of synonyms should not both be listed in the same way; a distinction should be made. The confusion in thought which results from the uncritical lumping of them in one list is betrayed by certain other features of the citation. Of what is *Ranunculus hispidus* var. *typicus* a "nom. nov."? Clearly, in the ordinary nomenclatural sense, it is a new name for the variety, which was previously named *Ranunculus repens* var. *hispidus,* and is therefore superfluous when published and illegitimate. It is not a new name for the species, since a species cannot be named by a trinomial. It *may* possibly be regarded as a *new name for the type;* but this only becomes intelligible if the main thesis already enunciated is granted: that names are the names of types, and of types only. If species and variety may have the same type (and, for that matter, family and order and class), then obviously *the same type may have several names* at different levels in the hierarchy.

Name, Circumscription and Authority. Historically, the citation of the author of a name has served both as a bibliographic guide to the original description, and, as homonyms began to accumulate, as a practical aid in the establishment of a reasonable stability in the application of the name. The wider dissemination of botanical literature and the publication of special indexes (e.g., the *Index kewensis*), together with the general acceptance of the DeCandollean principle of priority, has rendered the function of the citation of authority less important than formerly, except in the more technical systematic works.

As has been set forth in the earlier paragraphs of this paper, with the adoption of the type method botanical names became, for nomenclatural

[9] It must be emphasized that this work is picked at random (chiefly because it had been recently consulted) as entirely characteristic of modern taxonomic work; we intend no criticism of this author for conforming to the modern idiom.

purposes, the names of types. A corollary is that the current practice of the citation of authority has lost its former function and today serves primarily as a bibliographic tool connected with reference to the nomenclatural type. Certainly it is quite unrealistic to assume that the original author is to be held responsble for subsequent interpretations (circumscriptions). To make such an assumption is to admit openly that we have made no advance in biological thought in the last century or so and still hold firmly to the doctrine of special creation—that the individuals of a species are all essentially alike and the original description is adequate for all time as a circumscription of the taxon.

We glibly write "*Magnolia virginiana* L." assuming that we are being nomenclaturally quite precise. As has already been made plain, Linnaeus had several quite different interpretations of the group associated with this name, one of them including various taxa we now recognize as distinct species under a series of names. To achieve the desired clarity, therefore, all that would seem necessary is to append the date of the concept we wish to use. Unfortunately Linnaeus abandoned the epithet *virginiana*, and our species is *M. glauca* L. 1759—an illegitimate name because superfluous when published. If he *had* continued to use *M. virginiana*, the name of 1759 could not be used as distinct from its earlier homonym of 1753. At this point—if he did not before—the reader will comprehend why we are forced to point out that, nomenclaturally, botanical names are the names of types, that only secondarily do they become functional as the names of taxa. As the names of types they are immutable, except by deliberation and legislation; as the names of taxa they are subject to personal interpretation and, like botanical weathervanes, to the whim of every taxonomic wind that blows.

As a further example we have previously noted *Erigeron foliosus* Nutt. Cronquist's circumscription of a taxon bearing this name (1947) included types of additional items named by Nuttall himself, by Torrey and Gray, by Heller, by Jepson, by Howell, and an additional nine chloronyms.[10] Whose circumscription—whose species—is it? Certainly it is not Nuttall's, since it includes the type of a name which he himself recognized as belonging to a different taxon. The only point in common between Nuttall's original concept and Cronquist's circumscription of more than a century later is in Nuttall's type of the name *Erigeron foliosus*. It is quite likely, just as Cronquist differed in his circumscription from Nuttall, Torrey and Gray, Heller, Jepson, Howell, and Greene, so will subsequent authors differ from Cronquist; this is inevitable.

[10] The term chloronym was proposed by the late John Hendley Barnhart for binomials created by E. L. Greene; perhaps in mild retaliation for Greene's bitter diatribes at Barnhart's efforts to stabilize nomenclature by means of an impartially applied set of rules, devoid of the confusing exceptions and legal loopholes characteristic of the so-called international rules then current.

Let us, for example, suppose that another revision of *Erigeron* should appear in the near future, arrived at through experimental methods, and under the authorship of John Doe. In it would be a treatment of *E. foliosus* differing considerably from Cronquist's in circumscription. (Doe's circumscription would of course include Nuttall's type.) Shortly thereafter Richard Roe would be working on an ecological problem wherein it was necessary to identify a series of Erigerons. It would first be necessary for him to decide whether he would use Cronquist's or Doe's treatment of the genus in identifying his material. Let us say that he chooses Doe's treatment as being more objective, since in it Doe demonstrated that several of the taxa reduced to synonymy by Cronquist actually were parts of other biotic populations. In arriving at his identifications Roe finds material of *E. foliosus* and lists it in his work. He is then confronted with the problem of how it is to be cited so as to indicate clearly whose treatment of the group he followed in this particular study. This might be done by a special note appended to the text, stating that in his analysis of *Erigeron* he had used Doe's treatment. However, if the text is long and covers a wide range of taxonomic groups, this system would become cumbersome. The ecologist Roe is therefore more likely to follow current practice, listing his plants merely as "*Erigeron foliosus* Nutt.," and thereby making it impossible for his readers—who possibly might be interested in precision—to ascertain just what it was he had in hand.

This may not be cause for great concern to the professional taxonomist who deals primarily with extensive revisions and who—if the truth may be told—seldom places much confidence in the decisions of his fellow taxonomists. But the far larger group of workers who, perforce, must rely on the professional taxonomist for their technical plant names find this situation a real problem. Articles 47 and 50 clearly imply that a "considerable" change of circumscription (with, of course, retention of the type of the name) requires the addition of a term such as *mutatis charact.* or *emend.*, followed by the name of the author making the recircumscription (the rules are silent on what constitutes a "considerable" change; and perhaps rightly, since such judgments are taxonomic). Although one of the really critical means of bridging the gap between nomenclature and taxonomy, the device is so rarely used that it is evident that it is not (as advised in Art. 3) a part of the rules "sufficiently clear and forcible for everyone to comprehend and be disposed to accept."

We therefore wonder whether, when it seems necessary or expedient to indicate the author of a circumscription or diagnosis which is at variance with the original, the author of the later circumscription should not be designated by some suitable typographical device, such as by inclusion in brackets. For example: *Erigeron foliosus* Nutt. [Cronquist]. In his pub-

lished work the ecologist Roe would write it as *Erigeron foliosus* Nutt. [Doe]. In certain usages the date also should be inserted, thus: *Vaccinium corymbosum* L. [Camp 1945]; here, because of additional cytogenetic investigation revealing the presence of non-interbreeding diploids and tetraploids, it was found necessary to revise a former (1940) circumscription by the same author which, unfortunately, had been adopted by Rehder in his widely used *Manual*.

When it is once fully recognized that the citation of authority for the majority of names involves two quite separate ideas—one (nomenclatural), the authority for the name of the type; the other (taxonomic), the authority for a later circumscription of the taxon which includes the type—the need for a double citation of authority will become evident. In our opinion, acceptance of the foregoing suggestion, or something similar to it, would clarify much of the confusion surrounding the use of names in botanical literature. In fact, even if it be heresy, we would go so far as to say that, in all but the more technical revisionary works, it might be expedient to omit the authority for the name of the type and indicate, in brackets or by some other device, only the authority for the circumscription used. For all practical purposes in the *use* of the name, "*Magnolia virginiana* [Rehder 1947, 1949]" is of far greater significance than "*Magnolia virginiana* L." In Rehder's *Manual* of 1947 one will find a generally acceptable description (circumscription, of the taxon associated with the name—or at least that which this author used; and in his *Bibliography* of 1949 one will discover an excellent summary of the history of the pertinent background in the nomenclature of this and related taxa. Neither of these items could be found in the writings of Linnaeus, no matter how long one should pore over them.

It is inevitable, especially with the advent of experimental taxonomy, that there will often be two essentially contemporaneous treatments of the same group. The classical and experimental taxonomists will both use the same names and types, yet their circumscriptions may differ widely. Now, as never before in the history of plant taxonomy, there is need for a citation of the author of the circumscription in addition to (or, in the less technical works, instead of) the author of the name of the type. This situation is likely to persist for a long period and we should be prepared to meet it with an adequate addition to our devices for clarifying the application and use of botanical names.

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THE ACADEMY OF NATURAL SCIENCES OF
PHILADELPHIA

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BULLETIN OF THE TORREY BOTANICAL CLUB
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INHIBITION OF GROWTH AND CELL DIVISION IN ONION ROOTS BY MALEIC HYDRAZIDE

VICTOR A. GREULACH AND EARLENE ATCHISON

Schoene and Hoffman (1949) found that maleic hydrazide inhibited plant growth without seriously injuring the plants, and more recently Naylor and Davis (1949) and Greulach (1950) have provided additional data. While the maleic hydrazide may be more injurious than Schoene and Hoffman believed, even 2000 ppm., which completely inhibits apical growth, does not kill most plants. Currier and Crafts (1950) recently reported that a 0.2% solution of maleic hydrazide eventually kills barley but not cotton. There has been no report which indicates whether growth inhibition is due to interference with cell division or cell enlargement or both.

In an effort to clarify this point onion roots were allowed to develop in solutions of the diethanolamine salt of maleic hydrazide (MH) and their rates of growth and cell division were determined. Bulbs of Southport Yellow Globe onions (*Allium cepa* L.) were selected for uniformity of size and placed on new vertical Coplin staining jars filled with water. Three days later roots had developed to a mean length of 1.5 cm. At this time the bulbs were divided into 5 groups on 8 each. After determining the number of roots per bulb and the mean length of the roots on each bulb, one group of 8 was transferred to each of the following concentrations of MH: 1, 10, 100, 1000 ppm. One group of 8 was left in distilled water as a control. Twenty-four hours later 4 bulbs from each group were transferred to distilled water; 4 were retained in the solutions throughout the experiments. Fresh solutions and water were provided 3 days after the treatments began. All plants were maintained in a dark room, at a temperature of about 25° C, but were exposed to dim light while the data were taken and at a few other times.

Determinations of root length and number were made 24, 48, 72, and 216 hours after the treatments were begun. At the first 3 of these intervals 4 root-tips were cut from each bulb, stained by the Feulgen method, embedded in paraffin, and sectioned at 15 microns. Median longitudinal sections were selected for determinations of cell size and mitotic activity, the number of metaphases and anaphases per 400× field being used as an

index of the latter. The data given are based on the mean number per field from counts of 50 fields from each treatment.

Attempts to determine the effect on individual cell enlargement were unsuccessful because it was not possible to select accurately a section area which would be constant for all roots.

In another experiment 5 bulbs were placed in 2000 ppm. MH, 5 in distilled water, and observations similar to the above were recorded.

Effect of MH on total growth in length. Figures 1 and 2 indicate the relationship between MH concentration and terminal root growth in length and number. The data do not include the 10 ppm. solution. Within 48 hours after the initial treatment the roots in this concentration were brown and flaccid, while in all other treatments except with 2000 ppm. the roots were white, turgid and healthy. The mean length and the number of roots in the 10 ppm. solution did not increase at all in the continuous series, or in the transfers up to 72 hours. However, by the end of the experiment roots on the transfers had grown to a mean length of 5.5 cm., as compared with 4.3 cm. for the controls. It was found that the 10 ppm. solution had a pH of 5.8 as compared with 6.8 for the 1 and 100 ppm. solutions, 7.8 for the 1000 and 2000 ppm. solutions. It is probable that the 10 ppm. solution was contaminated, possibly by a bottle which had not been thoroughly rinsed and which contained some acid. The extreme growth-inhibiting properties of this solution can hardly be explained on the basis of the lower pH alone, but was probably due to the formation of a more active compound of MH.

As indicated by figure 1, the growth-inhibiting properties of the MH solutions were in the order of their concentration, but 100 ppm. was little more effective than 1 ppm., while 1000 ppm. completely inhibited growth. The recovery which occurred in the groups transferred back to water is evident in figure 1b. The MH solutions also reduced the number of roots produced in the order of their concentration (fig. 2), except that 1 ppm. was completely ineffective in this respect. Moreover, the 1 ppm. transfers produced many more roots than any of the other groups, including the controls. This may represent a residual stimulating effect of very low concentrations of MH.

With 2000 ppm. there was 93% inhibition of root formation, and those roots which were formed were less than 0.5 cm. long and were bent at an angle of almost 90° at their mid-points.

The inhibition of root formation was not generally as marked as the inhibition of growth in length. Even in the continuous series only the 1000 ppm. solution exerted a marked continuing inhibition of root formation, and this was not complete. Except for the 1000 and 2000 ppm.

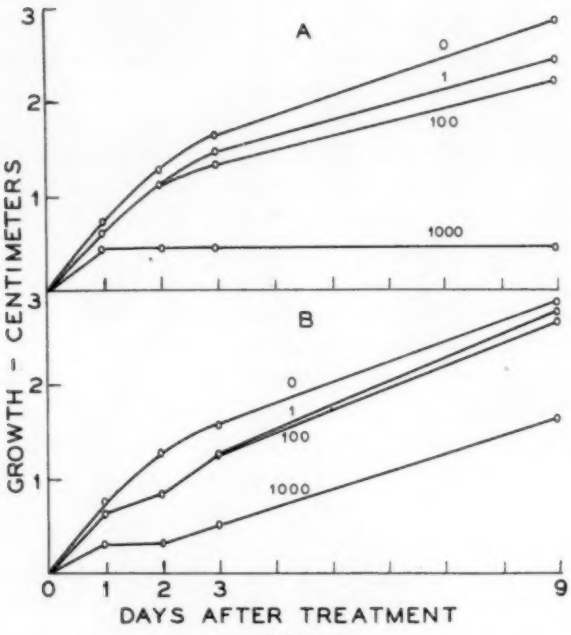
A
B
0
1
100
1000
GROWTH - CENTIMETERS
DAYS AFTER TREATMENT

FIG. 1

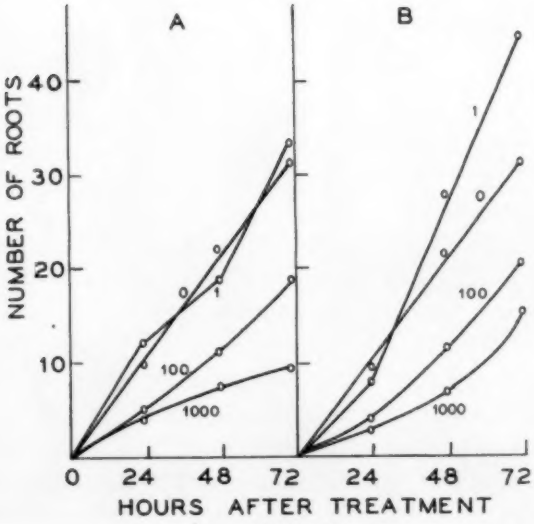
A
B
NUMBER OF ROOTS
HOURS AFTER TREATMENT

FIG. 2

groups all bulbs had large, approximately equal, numbers of roots by the end of the experiment.

Effect of MH on cell division. MH solutions definitely inhibited mitosis and cell division in the order of their concentrations (fig. 3). The rather high rate of cell division in the 1 ppm. continuous series at the 48-hour interval is probably due to the use of roots for cytological study which had only recently been formed by the bulbs; it can be seen in figure 2 that there was a pronounced increase in number of roots on bulbs in this series

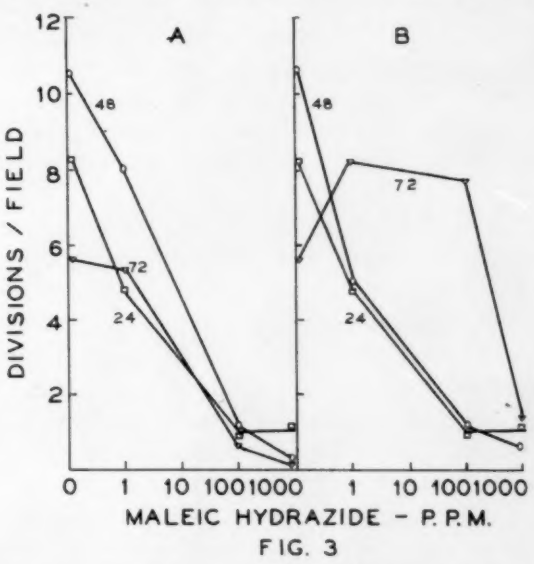

FIG. 3

FIGS. 1–3. Fig. 1. Effect of maleic hydrazide on growth in length of onion roots. A. Roots retained continuously in MH. B. Roots transferred to water after 24 hours. The figures on the curves show concentrations of MH in ppm. Fig. 2. Effect of maleic hydrazide on the number of onion roots developed after the treatments began. A. Roots retained continuously in MH. B. Roots transferred to water after 24 hours. Fig. 3. Semi-log graph of influence of maleic hydrazide on number of cell divisions (metaphases and anaphases) per field. Data based on average of 50 fields per treatment. The figures on the curves refer to the number of hours after treatment at which the data were secured.

during the 24–48 hour interval. With the exception of the 1000 ppm. continuous treatment no abnormalities in the general structure of the nucleus, cell or root were observed. None of the anaphases or metaphases were polyploid, as was reported by Giles (1948) from treatment of *Allium* and *Narcissus* roots with various other growth-inhibiting substances. Mitotic activity was resumed in all of the transfers, with the rate of recovery somewhat correlated with the concentration of the solution to which the

cells had been exposed. Recovery was marked in the 1 and 100 ppm. transfers, but slight or delayed in the 1000 ppm. transfers.

Roots exposed continuously to 1000 ppm. MH showed various deleterious effects on cellular structure, though these effects were not constant for every root-tip. Many nuclei were misshapen and darkly stained, and the meristematic region was considerably shortened. The lamellae between cells were degenerating and the cortical region less differentiated. Meristematic division had completely stopped.

Only 2 root-tips were removed from the 2000 ppm. solutions for cytological study. These had an extremely short meristematic region and the cortical tissue was degenerating. In the region of the 90° bends cortical tissue was almost completely absent. Individual cells showed the same general deleterious effects recorded for the 1000 ppm. treatment. Even these roots, however, contained a number of normal, apparently healthy cells.

Discussion. Although reduction in cell division and in growth in length can both be correlated with the concentration of MH, the two curves cannot be superimposed readily upon each other. The inhibition of cell division by 100 ppm. was almost as complete as by 1000 ppm. This is in marked contrast to the effect on growth in length, where the 100 ppm. was little more effective than the 1 ppm. solution. Since only approximately one-fourth of total growth can be attributed to cell division, while the remainder results from cell enlargement, the two processes may have been separately affected. It is suggested that the 1 and 100 ppm. solutions may inhibit only division, while the 1000 ppm. solutions inhibit both division and enlargement. From the observations on transfers it seems likely that enlargement precedes division in order of recovery.

Apparently MH solutions can be used in certain concentrations to arrest cell division without permanent harmful effects on either cell structure or function.

SUMMARY

Roots of *Allium cepa* were treated with 1, 100, 1000 and 2000 ppm. solutions of maleic hydrazide, and observations were made on the inhibition of total growth and of cell division alone. The effects on both were in order of the concentration of the MH solutions, but the effect on cell division did not occur simultaneously with the effect on total growth. It is suggested that lower concentrations inhibit cell division but not cell enlargement, while higher concentrations inhibit both.

Deleterious effects on tissue structure were observed only among groups treated with solutions of 1000 and 2000 ppm. continuously. These were

also the only groups in which there was any failure of recovery from the treatment.

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NOTES ON GEOCARPON MINIMUM MACKENZIE

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Ecology. On April 17, 1949, we visited a locality near the northwest corner of Jasper County, Missouri, in the hope of rediscovering one of the rarest plants found in the range of Gray's Manual or that of Britton and Brown's Illustrated Flora. The expedition was successful and we found a considerable amount of flowering material for study and for herbarium specimens.

The type locality of *Geocarpon minimum* Mackenzie[1] is in Duvall Township, Jasper County, about three and a half miles north of the village of Alba and about an equal distance south of the Barton County line. At this point a conspicuous escarpment marks the southern limit of the Barton Upland with an abrupt change in geology and topography. Sandstone and shale of the Cherokee group of the Pennsylvania series here overlaps the Boone limestone of the Mississippian series which is covered and concealed by the alluvium of the valley of the North Fork of Spring River. The elevation of the upland is about 260 meters (850 ft.) above sea level. The surface of the high prairie near the escarpment is covered in many places by broken masses of heavily bedded sandstone that has been broken down by erosion, or the stratum is sometimes in place and exposed over small areas. Some of the displaced blocks are three or four decimeters thick and up to a meter or more in other dimensions. The thick sandstone ledges, interbedded with shale, are also exposed along some of the small streams that dissect the plateau. The sandstone is of a light brown or buff color and is composed of small grains of silica loosely cemented together. A fine sandy soil that has been more or less enriched with humus results from its disintegration. The change in geology, soil and topography is reflected in the flora, as a number of plants are found here that are characteristic of or peculiar to the region. The flora over the dry prairie is predominently herbaceous, with grasses, sedges, legumes and composites conspicuously represented. A few stunted persimmon trees, some rose and blackberry bushes, and rarely a few other woody plants occur among the sandstone rubble, and a number of other species along the small streams. Among characteristic species are *Andropogon ternarius, Panicum scoparium, Setaria imberbis, Rhynchospora*

[1] Torreya 14: 67. 1914.

globularis var. *recognita*, *R. glomerata* var. *minor*, *Scleria ciliata*, *S. triglomerata*, *Fimbristylis caroliniana*, *Carex umbellata*, *C. stipata*, *Tradescantia Tharpii*, *Anemone caroliniana*, *Rubus Bushii*, *Baptisia leucophaea*, *Centunculus minimus*, *Castilleja coccinea*, *Rhexia interior*, and *Cirsium discolor*.

Geocarpon minimum is found growing in thin sandy soil among the sandstone blocks where it becomes temporarily quite wet after rains but later extremely dry. Three or four distinct colonies have been located that occupy in the aggregate only a few square meters and are not more than twenty or thirty meters apart. The plant is sometimes quite abundant and dominant in these small areas, but so far it has been discovered nowhere else. The same formation with practically identical ecological conditions prevails over much larger areas and extends northward into Barton County, and a diligent search was made for it there, but without success. Both because of its inconspicuous character and brief vegetative period it could easily be overlooked, and it is, of course, quite possible that its range may be somewhat extended by further exploration.

Many of the plants are nearly simple and produce only one or two flowers and are scarcely more than a centimeter in height. Better developed specimens are branched from the base, three or four centimeters high and may have fifteen or more flowers. The dates of collections indicate the approximate time of anthesis and growth, but they may vary a week or two in different years due to variations in the season. The usual vegetative period is probably from about the middle of April to the middle of May. All known collections are from the type locality as follows:

E. J. Palmer, No. 3921 (type), April 20, 1913; No. 5517, May 7, 1914; No. 48567, April 17, 1949; No. 48625, May 17, 1949; *J. A. Steyermark*, No. 67200, April 17, 1949.

Morphology and taxonomy. In treating the Aizoaceae for the recent edition of Die Natürlichen Pflanzenfamilien (2. Auflage, Band 16 c, p. 233, 1934), Pax & Hoffmann, not having had access to material for study, placed *Geocarpon* at the end of the family, considering it as a genus of uncertain status ("unsichere Gattung").

Mackenzie, when describing this genus (Torreya 14: 67–68. 1914), was not certain of its position in the plant kingdom, for he says, "This plant is probably to be referred to the family Aizoaceae or as treated in the Synoptical Flora 1: 256, the Ficoideae, and to the tribe Aizoideae of that family. In many respects it seems to come closer to the genus *Cypselea* than to any other North American genus. It differs markedly in the absence of stipules and style and in the capsule not being circumscissile. The other genera of the

tribe in question, found in this country, are succulent plants with circumscissile capsules and cornute calyx lobes.

"The tribe Mollugineae of the same family characterized by a calyx divided nearly or quite to the base, and represented in the United States by two genera having 3-celled ovaries, is less closely related to our plant. Nor can our plant be considered an apetalous representative of the Alsinaceae, as the sepals in that family are distinct or very nearly so. It seems, in fact, to represent a well-characterized genus."

In his statement that the sepals in the Alsinaceae are "distinct or nearly so," Mackenzie unfortunately was laboring under a false assumption. Most authorities do not agree with Mackenzie and with Small in treating *Alsinaceae* and *Caryophyllaceae* as distinct families. Engler & Prantl, Engler-Gilg, Bentham & Hooker, Gray's Synoptical Flora, Gray's New Manual of Botany, Hegi, and practically all modern taxonomists consider the Alsinoideae as a subfamily or tribe of the Caryophyllaceae, instead of as a separate family. Moreover, *Geocarpon* cannot be excluded from the Caryophyllaceae on the basis of its gamosepalous calyx, since a number of genera in that family have this character, for example *Scleranthus*, which is placed in the tribe Alsinoideae by Pax & Hoffmann in their treatment in Engler-Prantl. In the tribe Paronychioideae, such genera as *Herniaria*, *Hectorella*, *Lyallia*, and *Thurya*, and in the tribe Silenoideae, *Silene*, *Lychnis*, *Agrostemma*, *Saponaria*, *Gypsophila*, *Tunica*, and *Dianthus*, all have the sepals united into a tube or cup.

In *Geocarpon* the stamens are inserted on the calyx tube (perigynous), but this is also the case in various other genera of the Caryophyllaceae, such as in *Scleranthus*, *Lyallia*, *Pycnophyllopsis*, and *Habrosia*, and throughout the tribe Silenoideae or Sileneae. In his description of the flower, Mackenzie overlooked a very important morphological feature. Under a dissecting binocular microscope, the opened flower shows five rudiments of staminodia alternating with five fertile stamens. These minute rudiments are inserted at the same level on the calyx tube, just below each sinus where two calyx lobes unite; they are about as broad as they are long and have a subtruncate tip (fig. 1, g, h). Although they are easily overlooked, they are quite significant, in that they indicate a condition of staminal reduction found in other members of the Caryophyllaceae. The stamens in this family are often 5 or 10, but in a number of genera with 5 stamens there are also 3–5 staminodia present. In the Caryophyllaceae, as indicated in the Pflanzenfamilien (loc. cit., pp. 281–282), the number of staminodia is limited to a tetramerous or pentamerous cycle, whereas in the Aizoaceae, for example in *Mesembryanthemum*, the number of staminodia is indefinite.

In *Geocarpon* the ovules are attached to a free central placenta of a 1-celled ovary, a character typical of the Caryophyllaceae (fig. 1, c, d, e). In the Aizoaceae a 1-celled ovary is an exception, a 2–many-celled condition being usual. The apetalous condition of *Geocarpon* is also shared by a number of genera of Caryophyllaceae.

In the light of these facts *Geocarpon* agrees in all characters with the Caryophyllaceae: lack of stipules, gamophyllous calyx, 5 perigynous stamens, 5 staminodial rudiments, 1-celled ovary, numerous amphitropous ovules on a free central placenta, 3 stigmas alternating with 3 tips of the valves of the ovary or capsule, and it must be considered a real member of this family.

Although Mackenzie describes the ovary as having "5 central placentae," examination of living material reveals but 1 free central placenta. Also, his description of the tips of the 3 valves of the capsule needs to be modified, for they are broadly ovoid and bilobed or emarginate at a subtruncate apex (fig. 1, a, b).

The genus *Geocarpon* possesses some characteristics of each of the subfamilies *Paronychioideae* and *Alsinoideae*, having the perianth segments united as in some members of the *Paronychioideae*, and lacking stipules like the *Alsinoideae*. Although it is difficult to decide with which of the subfamilies it is more closely related, it probably belongs near the tribe *Scleranthea* in the subfamily *Alsinoideae* because of the gamophyllous calyx, lack of petals, and perigynous stamens. Its numerous ovules, however, readily distinguish it from that tribe. Possibly it should be placed between the tribe *Alsineae*, subtribe *Sabulininae*, and the *Scleranthea*, representing a type with a reduced number of stamens (5) and five staminodia, while retaining the numerous ovules of other genera of the family.

On the other hand, it is also related to the tribe *Sperguleae*, subtribe *Spergulinae*, of the subfamily *Paronychioideae*, in having a capsular fruit, free stigmas, and a 1-celled ovary, but lacking stipules present in most members of this subfamily. In regard to the number of stamens and staminodia it is also related to such genera as *Polycarpon* and *Loeflingia*, tribe *Polycarpeae* of the subfamily *Paronychioideae*, but lacks the stipules and free sepals of these genera.

In most genera of the Caryophyllaceae the fertile cycle of stamens, when reduced to 5 or less, is opposite the sepals or calyx lobes; in *Geocarpon* these fertile stamens significantly alternate with the calyx lobes. Also, the cycle of staminodia in most of the Caryophyllaceae is alternate with the calyx lobes, or sepals, whereas in *Geocarpon* this cycle of staminodia is opposite. In this respect *Geocarpon* approaches *Scleranthus*, in some species of which the fertile stamens alternate with the calyx lobes.

In view of these considerations, *Geocarpon* may be considered as the type genus of a new tribe of the subfamily *Alsinoideae* as follows:

Subfamily *Alsinoideae*
Tribe *Alsineae*
Subtribe *Sabulininae*
Tribe *Geocarpeae*
Tribe *Scleranthеae*

Tribe *Geocarpeae* Palmer & Steyermark, tribus nova. Petala O. Calyx gamophyllus. Stamina 5. Staminodia 5. Ovula plurima. Stigmata 3, dentibus capsulae alternantia. Stipula O.

Type genus: *Geocarpon* Mackenzie. Torreya 14: 67–68. 1914.

This tribe is distinguished by the apetalous flower, gamophyllous calyx, 5 stamens, 5 staminodia, numerous ovules, and 3 stigmas alternating with an equal number of teeth of the capsule. It is related to such genera as *Scleranthus*, tribe *Scleranthеae*, which has only 1 ovule and 2 styles, and to such members of the tribe *Sabulininae* as *Lyallia* and *Thurya*.

SUMMARY

1. *Geocarpon minimum* is known to occur in only one locality, an area north of Alba in Jasper County, Missouri, where it is restricted to sandstone outcrops of Mississippian age of the Barton Upland. The genus is known nowhere else in the world.

2. Although Mackenzie had assigned the genus doubtfully to the Aizoaceae, examination of recently collected material furnishes new evidence, overlooked by Mackenzie, to show that the genus should be placed unquestionably in the Caryophyllaceae.

3. The lack of stipules, gamophyllous calyx, 5 perigynous stamens, 5 staminodial rudiments (a character not found by Mackenzie), 1-celled ovary, numerous amphitropous ovules on a free central placenta (misinterpreted by Mackenzie), 3 stigmas alternating with 3 tips of the valves of the ovary or capsule, furnish a combination of morphological characters shared by various genera of the Caryophyllaceae.

4. While possessing some characteristics of each of the subfamilies *Paronychioideae* and *Alsinoideae*, it probably belongs near the tribe *Scleranthеae* in the subfamily *Alsinoideae* because of the gamophyllous calyx, lack of petals, and perigynous stamens.

5. It is considered the type of a new tribe *Geocarpeae* Palmer & Steyermark, distinguished by the apetalous flower, gamophyllous calyx, 5 stamens, 5 staminodia, numerous ovules, and 3 stigmas alternating with an equal number of teeth of the capsule. This tribe is placed in the subfamily *Alsinoideae* between the tribe *Alsineae*, subtribe *Sabulininae*, and the tribe *Scleranthеae*, according to the arrangement of tribes in Pax & Hoffmann's

treatment in the latest edition of Engler-Prantl's Die Natürlichen Pflanzenfamilien.

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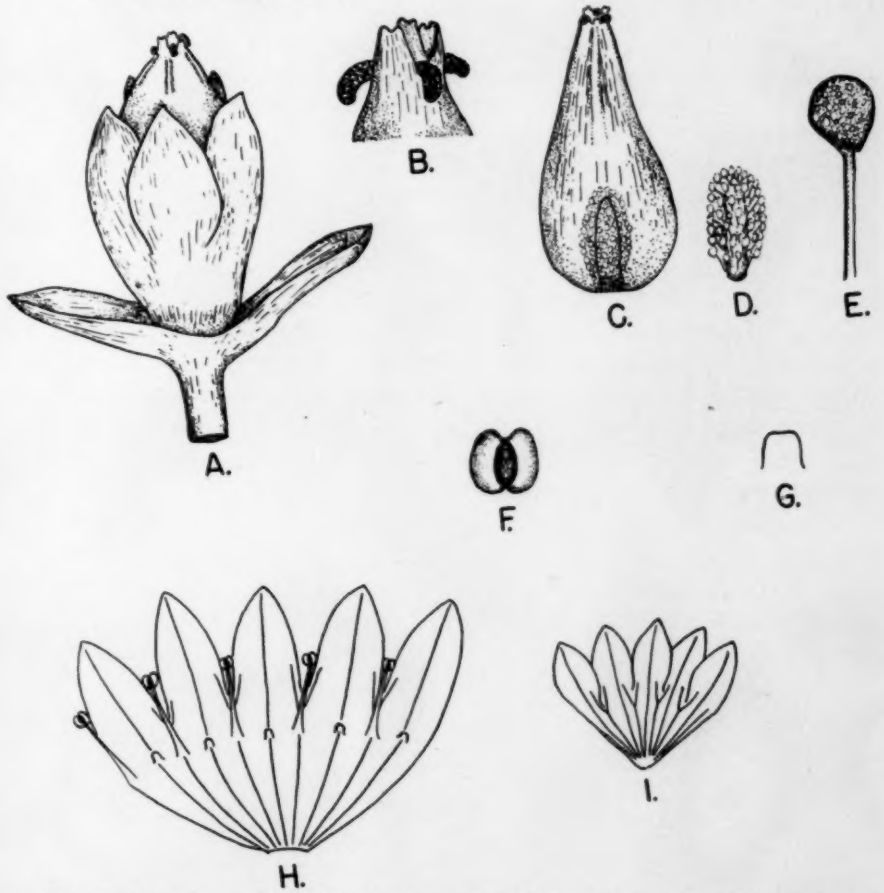

FIG. 1. *Geocarpon minimum* Mackenzie. a. Single flower in position (×10). b. Detail of bilobed capsular valves with squarrose stigmas (highly magnified). c. Mature pistil (×10). d. Placenta removed from ovary with attached ovules (×10). e. Single ovule on funicle (highly magnified). f. Detached anther (highly magnified). g. Detached staminodium rudiment (highly magnified). h. Perianth opened to show attachment of stamens and staminodial rudiments (×10). i. Perianth opened to show imbricate calyx lobes (×3½).

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THE DEVELOPMENTAL MORPHOLOGY OF THE MUTANT "CORN GRASS"

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One of the most fruitful approaches to the problems of developmental genetics lies in the detailed comparison of mutants with the normal or wild types from which they have arisen. In a few cases a single gene mutation, or a change in only a small segment of a chromosome, results in a great modification of the developmental pattern of an organism without an attendant decrease in vigor. An excellent example is the mutation in maize first reported by Singleton in 1947 and originally referred to as a second "teopod" mutation. This mutant was discovered in a field of sweet corn in New Jersey. It has now been given the name "corn grass" because of its close resemblance to grasses other than corn. Singleton has reported (1949) that apparently only a single mutation or at most a change in a short chromosomal segment is involved in producing the differences between "corn grass" and normal maize. He has postulated that corn grass may represent a possible ancestral type of modern corn, and he has raised the interesting question as to whether, if such an abrupt change from normal corn to a like type can be made at one "jump," is it necessary to postulate as many steps as are commonly assumed in the evolution of modern corn.

From a morphological standpoint, the differences between corn grass and normal corn are great, although the exact nature of these differences depends somewhat upon the conditions under which the plants are grown. It is the purpose of this paper to analyze the nature of these differences and to attempt to designate the possible level of the gene action involved.

Materials and Methods. Seed for the present study were kindly furnished by Dr. W. R. Singleton, first from the Connecticut Agricultural Experiment Station, and later from the Brookhaven National Laboratory. For the studies reported here plants of "corn grass" were grown in the field in the summers of 1948 and 1949 and in the greenhouse in the summer and fall of 1948 and the winter and spring of 1949.

The field plantings were made early in May of each year in The University of Texas experimental field in Austin, Texas. Plants grown in the greenhouse during the fall, winter, or early spring were given supplementary light for such a period as to make the total light period not less than fourteen hours.

As has already been noted by Singleton, (1949), the behavior of the plants in the field and in the greenhouse is quite different. All the anatomical data are based upon greenhouse-grown plants.

Results and Discussion. Figure 1A shows a field-grown corn grass plant at a stage approaching maturity. Figure 1B shows a greenhouse-grown plant of approximately the same age. Figures 2A and 2B present a comparison of seedings of corn grass and normal corn.

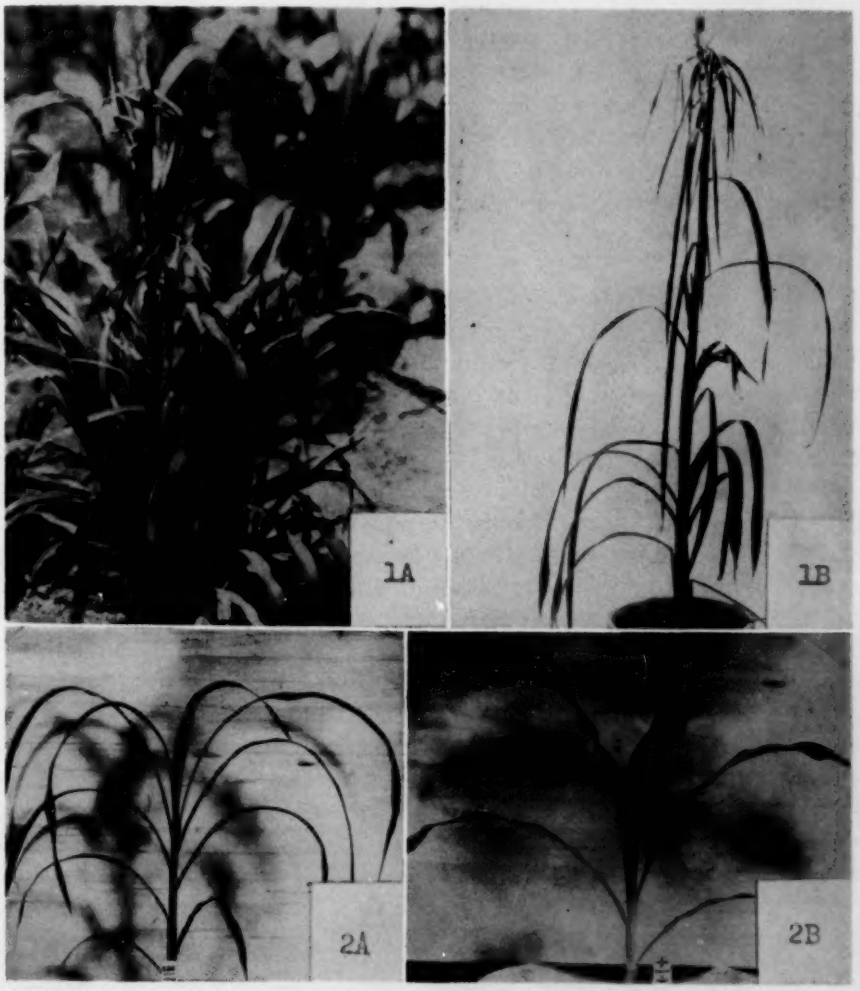

FIG. 1A. A field-grown corn-grass plant. This photograph was taken just prior to the appearance of the flowering structures. (Courtesy of Dr. W. R. Singleton.) FIG. 1B. A greenhouse-grown corn-grass plant of approximately the same age as that shown in A. FIG. 2A. A seedling corn-grass plant. FIG. 2B. A normal corn seedling of the same age as the corn-grass seedling in A. Note the differences in leaf number and leaf size.

All the plants grown in the greenhouse in this experiment were tall. Singleton reports (1949) that the plants grown in the Brookhaven National Laboratory greenhouses were not tall if planted during early winter. All of our field-grown plants were relatively short and tillered profusely. The similarity between field-grown plants of corn grass and certain weed grasses is so great that in The University of Texas experimental field in which Johnsongrass (*Sorghum halepense* (L.) Pers.) is a pest it was difficult to keep plants of corn grass from being pulled out as Johnsongrass.

Singleton has reported (1949) that the much-tillered field-grown plants can be divided and propagated asexually. He has noted that in one instance a single clump of corn grass was divided into sixteen plants, each of which then made good growth. This property of asexual propagation makes it possible to maintain, at least for a period, clonal lines of corn grass.

Singleton suggests that the tillering is a photoperiodic response. He determined that when sowings were made in Brookhaven at intervals of two weeks, beginning on August 15, disappearance of the tillering habit took place in the sowing made on November 1. In his studies, greenhouse-grown corn grass which did not have supplemental light was reported to produce fewer tillers than plants grown in the field. In our studies in which the greenhouse-grown plants did have supplemental light, there was no tillering. The relative rôles of light and temperature in this tillering response remain to be worked out.

For studies of the morphology of the seedlings, corn grass seed and seed of a control line of "normal" corn were planted in the greenhouse on July 21, 1948. This corn grass seed was of a heterozygous stock which segregated, giving corn grass plants and "normal" plants presumably differing from the corn grass in only the single mutation or chromosome change. In the segregating populations the corn grass plants can be identified by the larger number of leaves and differences in leaf shape. The seedlings were grown in flats of sand and were later transferred to sand in individual pots in which they were watered with a nutrient solution. Sample plants were collected at two-day intervals for about three weeks after emergence; then samplings were made at somewhat greater intervals. At each sampling care was taken to select plants which seemed typical for the stage of development. After the sample plants were selected the sand was washed from the roots of the selected plants and the roots were cut from the plants to permit weighing the roots and the shoot separately. After the weighings had been made, the leaves were removed from the stem and each leaf blade was measured individually. The length of each internode was then determined.

Table 1 gives shoot and root weights and shoot/root weight ratios at various stages of development for typical corn grass and normal plants

TABLE 1. *Increase in fresh weight of greenhouse-grown plants (Milligrams).*

Age in days	Shoot			Root			Shoot/Root Ratio		
	Corn Grass	"Normal"	857	Corn Grass	"Normal"	857	Corn Grass	"Normal"	857
2	362	285		216	260		1.68	1.10	
4	738	400		1051	528		0.70	0.76	
6	809	445	582	1555	755	285	0.52	0.59	2.04
8	2130	1450	870	4980	2720	710	0.43	0.53	1.22
12	3050	2370	1050	4460	2880	1030	0.68	0.82	1.02
16	3150	2970	2520		3150	1670		0.94	1.51
18	4970	4370		5870	3620	1320	0.85	1.21	
24	12250	10450	3500	8150	4080	1620	1.50	2.56	2.16
39			9000		7550	7620			
43	14220		11300	16650	5220	10020	0.85		1.13
47		21100	22900		13500	13450			
68	17700	27320	41400	14500	16480	16000	1.22	1.66	2.59

segregating from the corn grass population, as well as, for further comparison, plants of line 857, a standard normal stock.

The data indicate that during the early stages of growth the corn grass shoots increased more rapidly than those of either of the "normal" controls. This more rapid increase was apparently associated with the more rapid formation of leaves by the corn grass plant. As the corn grass plant matured, it lost its advantage in shoot weight, because although it formed many more leaves, its total leaf mass at maturity was significantly less than that of the normal types. Corn grass plants also attained an early advantage in root weight. Like the advantage in shoot weight, this root weight advantage was lost with the approach of maturity. The data for 68-day old plants suggest that there were no distinct root weight differences between corn grass and the normal plants. Inasmuch as the pattern of root development was not studied, there is no indication of the reason for the early-developed advantage in the root weight of the corn grass plants.

The method of sampling individual plants made it impossible to draw any significant conclusions from the shoot-root ratio figures. It is apparent, however, that in corn grass and both of the normal types there was a decrease in the shoot-root ratio during the early part of the developmental period. First, shoot growth was more rapid than root growth, then root growth tended to catch up. During the latter part of the growth period there was an increase in the shoot-root ratio indicating again a predominance of shoot growth.

The figures in Table 1 show clearly that for the first several weeks the corn grass grew more rapidly than either the normals from the segregating population or the 857 control stock. At maturity, however, the corn grass plants were smaller than either the normals from the segregating population or the 857 plants. It is perhaps of importance that with respect to shoot size, at least, the normal plants from the segregating population were smaller at maturity than are those of line 857.

To study the origin of the quantitative growth differences which are apparent in the maturing plants serial transverse sections were made of the shoot apices of mutant plants and the 857 controls. Shoot apical meristem volumes were calculated by measuring the diameters (actually the averages of the longest and shortest diameters) of each successive serial section through the meristematic portion of the shoot apex, the portion above the first clearly detectable leaf primordium. Since the thickness of each section was known its volume could be calculated by using the formula for the volume of a cylinder. The sum of the section volumes was taken as the meristem volume.

TABLE 2. *Volumes of seedling shoot apical meristems. Cubic micra.*

Age in days	Corn grass	857
8	695,000	562,000
14	920,000	673,000
20	966,000	629,000
24	1,430,000	672,000

As can be seen in Table 2, at the age of eight days the shoot meristem of the corn grass plant had a greater volume than that of the 857 control. Change in the volume of the meristem of the control plant between the 8th and 24th day was relatively small, but there was a big increase in the volume of the corn grass plant meristem in this same period. Despite the fact that the comparison presented is between two different genetic stocks the differences in meristem volume in this early growth period are so great that there can hardly be any question of their significance. It was not practical to attempt comparisons of the meristem volumes of older, more mature plants because during the period of very rapid leaf formation and development which came with the grand period of growth, the outlines of the actual shoot apical meristems became difficult to determine, and because in the later stages of development the shoot apical meristems became transformed into floral apices.

The apparent constancy of the meristem volume in line 857 is probably correlated with the relatively uniform rate of leaf production. The corn grass plants had a much heightened rate of leaf production during part of the growth cycle. The increase in the corn grass shoot apical meristem volumes, more than a doubling, was presumably associated with this much more rapid rate of leaf formation. The progressive increase in meristem volumes noted here is in agreement with the earlier findings of Abbe, *et al.*, (1941).

Not only was the rate of leaf formation by the corn grass shoot apex more rapid than that of the normal shoot apex but also the number of leaves formed by the corn grass shoot apex greatly exceeded the number formed by the normal apex. These differences are shown in Table 3.

It is obvious from our study that the basic morphological differences between corn grass and normal corn have their origin in differences in the shoot apical meristem.

The pattern of development which is unfolded by the shoot apical meristem of corn grass is distinctly different from that unfolded by the shoot apex of the normal plant. In corn grass plants less than two weeks old there was usually not a significantly greater number of leaves and leaf primordia

TABLE 3. *Leaf Number.*

Age in Days	Corn Grass	"Normal"	857
16	6	5	6
20	8	7	6
24	8	8	8
27	10	8	8
31	11	9	9
36	14	11	9
43	17	10	11
47	19	16	13
68	40	16	16
82	57		18
96			19

than in normal plants of the same age, although in some instances young corn grass plants had one, or sometimes two, more leaf primordia than did the normal pants. In any case, when growth of the plants began to become rapid there was characteristically an acceleration in the formation of leaf primordia in the corn grass plants so that by the time the plants were 30 days or more old and the leaves had begun to unroll in considerable numbers, the corn grass plants had many more leaves than the normal plants. Corn grass plants frequently branch considerably. In plants in which there is branching, the number of leaves is much greater than is set forth in Table 3.

At maturity, plants of line 857 had 19 leaves. (Table 3.) A more extensive study of this same plant reported by Whaley, *et al.*, (1950) indicates from 19 to 21 leaves as the normal number expected in this line of maize. The "normal" segregating plants from the heterozygous corn grass population typically formed only 16 leaves under the conditions of this experiment. The corn grass plants formed 57 leaves during this particular growth period and under other conditions as many as 70 leaves have been counted.

From a developmental standpoint, it is probable that the total area of leaf surface is of more importance than the number of leaves, inasmuch as total leaf surface area is a determining factor in the amount of photosynthesis which a plant can carry on, and hence the amount of food material which is available to the growing tissues.

Leaf blade area was calculated by multiplying the length of each leaf by its width at the widest part and deducting one-fifth of the result to correct for the tapering near the apex. Total leaf areas for corn grass and normal plants at different stages in development are given in Table 4.

The corn grass plants gain an early advantage in total leaf area (Table 4) because of the large number of leaves which are formed relatively early in development. Inasmuch as these leaves grow less than those of the normal

TABLE 4. *Total leaf blade area per plant in square millimeters.*

Age in Days	Corn Grass	"Normal"	857
16	2564	2963	5760
20	4218	2658	8164
24	5418	8318	8950
27	9934	7884	18426
31	17109	13926	20884
36	29590	20362	26953
39	27812	33416	45398
43	55878		45988
47	59424	73871	79075
68	57026	95293	123025
75	105830		
82			234823
96	97980		253730

plants this advantage is lost and as the plants approach maturity the total leaf surface area of the corn grass plants, despite the larger number of leaves, is less than that of either the normal plants in the segregating population or the plants of the 857 population. Line 857 is a line with a much larger total leaf surface area than that of the segregating normal plants. To permit making comparisons of the morphology of corn grass leaves with normal leaves, length and width measurements were made, at successive developmental stages, on the sixth and twelfth leaves on corn grass and normal plants. The results of these measurements are set forth in Table 5. As can be seen from the figures in the table, the 6th leaf of corn grass grows much more rapidly in length than the normal 6th leaf but does not achieve as great a length. The width of the corn grass leaves is consistently less than that of normal leaves and the leaf area is less. It is also apparent from the figures that the growth of the corn grass leaves is completed earlier than that of corresponding leaves of normal plants.

Abbe, *et al.*, (1941) found a correlation between the increase in relative width of the blades of leaves 6 through 12 and the increase in size of the shoot apical meristem from which the leaf initials arose. From the present study it was impossible to determine whether this correlation between a leaf dimension and the size of the shoot apical meristem exists in this particular material.

The corn grass plants differ from the normals not only in the number of leaves to which the shoot apex gives rise and the rate of their formation, but also in the pattern of leaf origin. The first leaves which are formed are so arranged as to appear nearly opposite. Later leaves assume the typical alternate appearance characteristic of normal corn plants. Then as the flowering stage is approached the leaves begin to be formed more rapidly and there is a modification of the stem structure which gives rise to an ap-

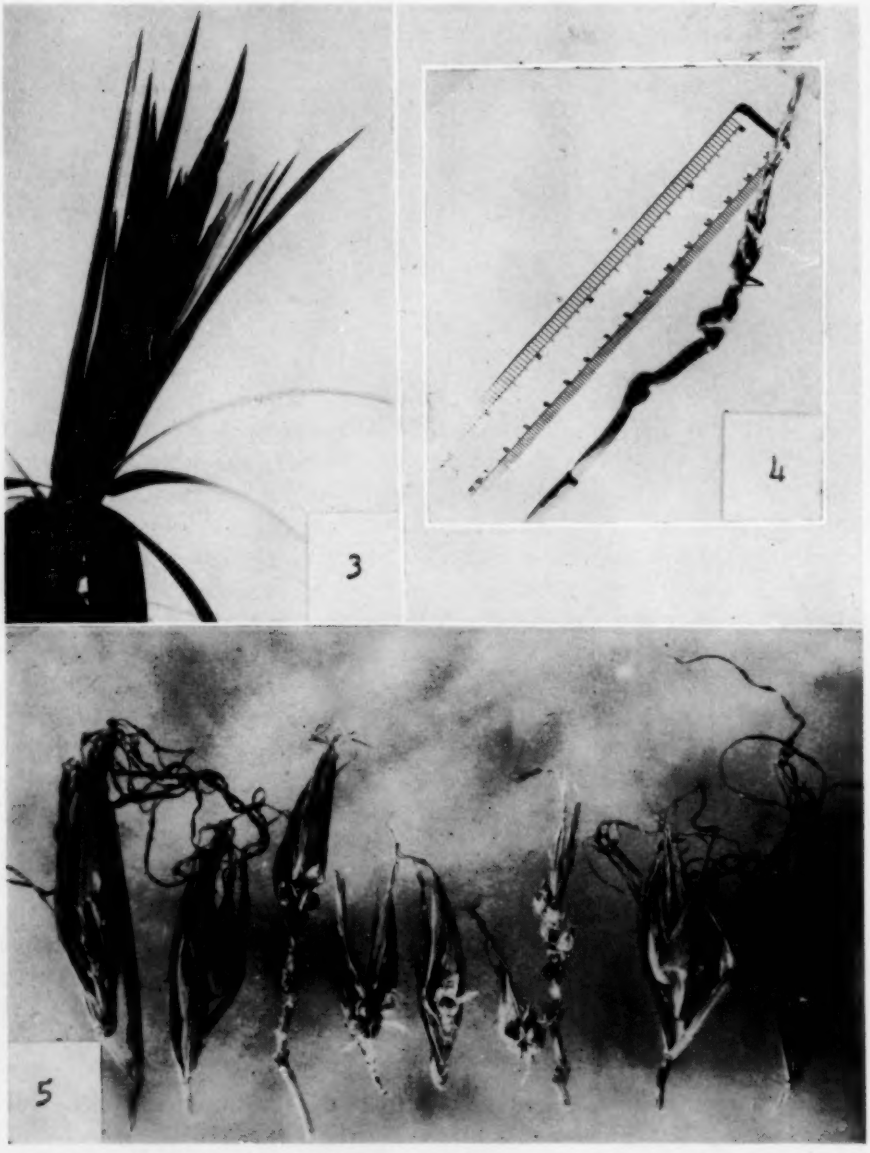

FIG. 3. The cluster of whorled leaves which surround the apical inflorescence of the corn-grass plant. There are ordinarily from 20 to 30 leaves in this cluster. FIG. 4. The upper portion of a corn-grass stem showing the aberrant growth of the more apical nodes and internodes. FIG. 5. Corn grass "ears." Note that each individual kernel is enclosed in a husk.

TABLE 5. *Dimensions of the 6th and 12th leaves of corn grass and line 857.*

Age in days	Length of Leaf		Width of Leaf		Leaf Area	
	Corn Grass	857	Corn Grass	857	Corn Grass	857
6th Leaf						
16	6	3				
20	58	8				
24	75	22				
27	241	106	15		2892	
31	225	236	14	28	2520	5286
36	282	340	15	32	3384	8704
39	260	450	15	38	3120	13680
43	315	408	18	29	4536	9466
12th Leaf						
43	465		22		8184	
47	455	22	22		8008	
68	370	618	19	44	5624	21753
75	510	635	23	62	9384	31496

pearance of whorled leaf arrangement. The cluster of apparently whorled leaves which both subtend the inflorescence and are scattered through it is shown in Figure 3.

The condition shown in Figures 3 and 4 appears to represent the same type of internode condensation discussed by Anderson (1944) and Stephens (1948). Both these investigators have given considerable attention to the developmental significance of this condensation and to its association with modifications of the ear and tassel morphology. Stephens has emphasized that the internode condensation is normally synchronized with the switch by the terminal meristem from vegetative activity to floral activity, but that under certain conditions condensation is characteristic of the vegetative phase of development. Our observations suggest that one of the major factors of the effect of varying the photoperiod upon the morphology of the corn grass plants may lie in the relative extent to which the condensation is apparent in the vegetative phase. It should also be pointed out that the appearance of the condensation may represent an early modified stage in the tassel development rather than an appearance of condensation during the vegetative phase.

By approximately two weeks after planting a greater number of nodes could be counted in the corn grass plants than in the normals. In all samples from that time on the number of nodes or internodes in corn grass greatly exceeded the number in normal plants. In one set of plants by the 82nd day after planting there were 34 internodes in the main stem of the corn grass. These internodes had a total length of 1,453 mm. At this same sampling period the normal plants had 19 internodes with the total length of 591 mm.

In addition the corn grass plant had a short branch from the thirteenth node and a long branch from the fourteenth node. The 13th node branch was too short to permit counting or measuring its internodes. The 14th node branch had 14 internodes and was 393 mm. long.

The stems of corn grass plants are invariably smaller in diameter than those of normal plants. In all the plants from either greenhouse or field cultures which were dissected the upper internodes which were condensed showed a "streak of lightning" configuration similar to, but more extreme than, that reported by Stephens (1948). Whether the condensation extends over a part of the vegetative stem or whether the whole condensation region is considered as being part of the tassel, the zig-zag configuration is marked in the tassel until in the more apical part the tassel stem becomes relatively small. Evidence pointing to the interpretation of this condensation region as part of the floral development is found in the fact that when there is more than one leaf at a node there is often either a staminate or pistillate spikelet in the axil of each leaf. Actually the leaves extend into what is clearly the flowering spike but not all the way up the spike, spikelets only being formed acropetally from the point of attachment of the last leaf. In some of the plants only terminal inflorescences are formed. In most plants, however, abortive branches bearing a small number of pistillate spikelets are formed at lower nodes. When such are present, they may include a few staminate spikelets. The flowering habit in the plants differs considerably in the field and in the greenhouse. Preliminary investigations have indicated the production of fair amounts of good pollen in the greenhouse and seed is set readily. Characteristically, less seed is set in the field.

Corn grass "ears" are shown in figure 5. The ears are small and characteristically contain less than 20 kernels. As in several supposedly primitive types of corn each individual kernel is enclosed in husks. Commonly a few seed were formed in the tassel structures. In the greenhouse-grown plants the tassels were variable structures, sometimes appearing essentially normal and at other times being much reduced.

The seeds are frequently very small and apparently malformed. In our experiments even the smallest, most malformed seeds germinated and grew.

Conclusion. Corn grass differs from normal corn as to a combination of characteristics which give an appearance similar to that of certain other types of grasses. That the shoot apical meristem of corn grass has a different activity pattern than that of normal corn is indicated by the greater number of leaves and internodes in the corn grass plants. A different pattern of meristematic activity is also involved in formation of the tassels by the floral apex. It may be supposed that the differences in form and size between corn grass leaves and stems and those of normal corn plants are also related to pattern development differences which are based on the activity of the

shoot apical meristems. It is clear that the shoot apical meristem of corn grass differs from that of normal corn as to volume, rate of change in volume during ontogeny and rate of leaf and stem segment formation activity. Correlated with this difference in rate of activity of the shoot apical meristem is more rapid general development and maturation in corn grass. Corn grass is distinguished by marked sensitivity to environmental factors which are presumably light or temperature or both. Its overall morphology is much more readily altered by variations in these factors than is the case in normal corn. In particular, stature and tillering are directly affected by these factors. Over a long period of time plants probably tend to accumulate modifiers which buffer the effects of environment. Selection must play a great part in the accumulation of these modifiers or the elimination of plants which do not contain them. It can be postulated that a mutant type such as corn grass may be without such modifiers.

If upon critical cytological examination corn grass proves to be the result of a single gene mutation or a very short chromosome alteration it will present another case among the higher plants in which several morphological characteristics are modified by a relatively minor genetic change. It is theoretically possible for a single gene mutation to result in alteration of some basic part of the plant's mechanism of growth pattern development and thus have a considerable number of end effects. The interpretation of corn grass as such an instance lays emphasis upon the necessity for considering level of gene action as well as the number of genetic changes when comparing different plant forms. The likelihood of single key changes resulting in as many differences as a large number of less fundamental changes cannot be overlooked in studies of such problems as the evolutionary development of the modern corn types.

SUMMARY

A developmental morphological analysis of the mutant "corn grass" reveals the differences between it and normal corn to be due to a different pattern of shoot apical meristem activity. Corn grass shoot apical meristems differ from those of normal corn in volume, in the rate of leaf primordium formation and the rate of stem tissue formation. Corn grass develops, in general, more rapidly than does normal corn. Corn grass appears to be more sensitive in its morphological responses to temperature and/or light factors than is normal corn. The significance of the production of major differences by single gene mutation is highlighted by this corn grass mutation.

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CONTROL OF BASAL ROT OF CUTTINGS OF CHRYSANTHEMUM AND OTHER ORNAMENTALS[1]

C. M. TOMPKINS AND JOHN T. MIDDLETON

Basal rot is a serious disease of cuttings of chrysanthemum (*Chrysanthemum morifolium* Ram.) in clothhouse cutting benches in San Mateo and Santa Clara counties, California. A similar rot affects cuttings of other ornamental plants in cutting benches in lathhouses and greenhouses in the same areas. The purpose of this paper is to report studies on the cause and control of this disease on cuttings of chrysanthemum and other ornamental plants.

Review of Literature. There are a number of reports on the rotting of plant cuttings, but few deal with the causal agents and the use of Ferbam,[2] Ziram,[3] and Spergon (tetrachloroquinone) as protective fungicides. Dietz (1944) has enumerated many different types of diseases affecting cultivated plants in the United States and successfully controlled by using Ferbam (Fermate) either as a dust or as a spray. McCallan (1946) has discussed control of certain diseases of fruit trees, vegetables, tobacco, and miscellaneous cuttings by applications of Ferbam.

In a preliminary note, Tompkins (1944) directed attention to a basal rot of soft-green cuttings of florists' chrysanthemum (*Chrysanthemum hortorum* Hort.), occurring each year, from January to April, in clothhouse cutting benches in San Mateo County, California. Three soil-inhabiting fungi, *Fusarium* sp., *Pythium* sp., and *Sclerotinia sclerotiorum* (Lib.) de Bary, were isolated from infected cuttings. Field tests indicated that the disease could be controlled by dusting the basal ends of the cuttings with Ferbam or a mixture of Ferbam and Celite 505 (a diotomaceous earth), Stoutemyer (1938) having suggested earlier that talc, a similar material is an excellent carrier of root-inducing substances used for dusting of cut-

[1] Paper No. 633, University of California Citrus Experiment Station, Riverside, California.

[2] "Ferbam" is the common name for ferric dimethyl dithiocarbamate (also known under the proprietary names of "Fermate" and "Karbam Black"), selected by the Subcommittee on Fungicide Nomenclature of the American Phytopathological Society, in cooperation with the Interdepartmental Committee on Pest Control, and filed with the Trade-Mark Division of the United States Patent Office.

[3] "Ziram" is the common name for zinc dimethyl dithiocarbamate (also known under the proprietary name of "Zerlate"), selected as described above.

tings. It was further suggested by Tompkins (1944) that Ferbam might prove equally beneficial on cuttings of other ornamentals. This suggestion was corroborated by Dimock, who reported satisfactory control of basal rot of cuttings of begonia (*Begonia* sp.), carnation (*Dianthus caryophyllus* L.), geranium (*Pelargonium* sp.), and poinsettia (*Euphorbia pulcherrima* Willd.) when the basal end was dusted with Ferbam or a mixture of Ferbam and talc (Anonymous, 1945).

White (1946) failed to control rot of geranium cuttings with Ferbam alone, but succeeded when Ferbam was used in combination with indolebutyric or naphthaleneacetic acids. The identity of the causal organisms was not revealed.

The prevention of scale rot in the propagation of bulbs of the Easter lily (*Lilium longiflorum* L.) by means of Ferbam was first indicated by Dimock (Anonymous, 1945). McClellan and Stuart (1945, 1946a, 1946b) have studied the effect of Ferbam and combinations of Ferbam and growth-promoting substances upon scale rot of Easter lily bulbs and decay of herbaceous cuttings.

Newton and Lines (1948) reported that the loss of cuttings of cypress (*Chamaecyparis lawsoniana* var. *allumi* (R. Smith) Beiss) was greatly diminished by dipping their bases into Ferbam or Spergon dusts. The causal organisms were not recorded.

Tompkins and Middleton (1950) have been able to control a stem and root disease of poinsettia cuttings either by dusting them with a mixture of Ferbam and Celite 505 prior to their insertion into the sand of the propagating bench, or by irrigating the sand with a water suspension of Ferbam.

Symptoms of the Disease. Chrysanthemum cuttings, which require four to six weeks for rooting under clothhouse conditions, seldom show foliar symptoms in the early stages of infection. The first expression of the disease is the appearance of one or more small to large, irregular-shaped, brownish-black, water-soaked lesions at or near the base of the cutting. Some of these lesions may later coalesce to form composite lesions encircling the stem. Infection may precede but usually follows callus and root formation. The stem tissues become blackened, flaccid, and shriveled as infection spreads upward toward the soil line. Discoloration of stem tissues above the soil line may be observed in advanced stages, and this is usually followed by stem collapse. The foliage usually wilts and may become chlorotic.

Roots of chrysanthemum cuttings are highly susceptible to infection, and when invaded turn brownish black, shrivel, and collapse. Infection of the roots and their subsequent destruction appear to hasten the spread of the disease in the stem tissues and to facilitate ultimate wilting and chlorosis of the foliage.

Symptoms of basal rot of other ornamental cuttings are similar to those described for chrysanthemum, except that infection usually precedes root formation, and tissue disintegration is more rapid.

Chrysanthemum and other ornamental cuttings are predisposed to infection by low air and soil temperatures and by excess water in the coarse sand used as a rooting medium in the clothhouses.

The Causal Fungus. Isolation. The original isolations made from chrysanthemum in 1944 yielded cultures of *Fusarium* sp., *Pythium* sp., and *Sclerotinia sclerotiorum*. Subsequent isolations yielded only a *Pythium* sp., which was identified as *P. ultimum* Trow. The fungus was readily obtained in pure culture from diseased specimens by tissue plantings made on cornmeal and plain water agars. The use of these media permitted isolations from badly diseased material without contamination. Pure cultures of *Pythium ultimum* were usually isolated in the same fashion from diseased material of other ornamentals.

Morphology. All the isolates of *Pythium ultimum* obtained agree with the description of the species as reported by Middleton (1943).

Temperature-Growth Relations. The relation of temperature to growth of the mycelium was determined for a number of isolates of *Pythium ultimum* from cuttings ofchrysanthemum, camellia (*Camellia japonica* L.), daphne (*Daphne odora* Thunb.), fuchsia (*Fuchsia hybrida* Voss), and gardenia (*Gardenia jasminoides* Ellis). The procedure and technique followed were the same as those reported earlier by Middleton (1942).

The average growth, in millimeters, over 24-hour periods at the various temperatures is presented in table 1. The cardinal temperatures for growth

TABLE 1. *Effect of temperature on mycelial growth of isolates of Pythium ultimum obtained from various ornamentals and grown on cornmeal agar.*

Isolates from:	Average growth in millimeters over 24-hour period at the following temperatures (°C.)													
	1°	4°	7°	10°	13°	16°	19°	22°	25°	28°	31°	34°	37°	40°
Chrysanthemum	t[a]	3	6	10	15	19	23	27	30	32	34	16	1	0
Camellia	1	2	4	7	13	18	26	32	37	40	32	14	1	0
Daphne	0	1	3	7	10	14	18	24	31	34	30	18	2	0
Fuchsia	0	1	4	7	12	16	19	23	27	29	24	7	0	0
Gardenia	1	3	5	8	12	17	22	28	35	38	31	18	2	0
Heather	t	2	4	7	10	14	18	23	27	28	21	9	t	0

[a] t = trace.

of the several isolates of *Pythium ultimum* are as follows (in degrees centigrade): minimum, 1°; optimum, 28°; maximum, 37°. These values conform with those given by Middleton (1943) for other isolates of *P. ultimum*.

Pathogenicity. In the spring of 1944 four flats filled with sand of the same grade as that used by growers in rooting chrysanthemum cuttings were steam-sterilized. Fifty cuttings of Pink Masaka chrysanthemum were placed in each flat. Inoculum was prepared by growing the three fungi, *Fusarium* sp., *Pythium ultimum*, and *Sclerotinia sclerotiorum*, on moistened, sterilized cracked wheat in 8-inch test tubes. The inoculum was removed from the tubes and placed in shallow trenches between the rows of cuttings; it was then covered with sand and watered. Sterile, moistened cracked wheat, only, was added to one flat of cuttings. These flats were placed in a lathhouse. Four weeks later 31 rooted cuttings showed basal stem and root infection in the flat infested with *P. ultimum*, whereas the cuttings in flats infested with *Fusarium* sp. and with *S. sclerotiorum* were not infected. The cuttings in the flat which received only sterile grain remained healthy. The fungus was reisolated in pure culture from each infected cutting.

The pathogenicity of two additional isolates of *Pythium ultimum* obtained in 1944 and 1945, to Pink Masaka cuttings, was determined in the same manner as described above. Of 50 cuttings inoculated with one isolate, 36 became infected, and of 50 cuttings inoculated with the other isolate, 39 became infected. Noninoculated cuttings remained healthy. The fungus was reisolated from each infected plant and proved to be identical with the original isolates. The reisolates were also highly pathogenic. All infected cuttings exhibited symptoms identical with those of naturally infected cuttings.

No inoculation tests were made with the numerous isolates of *Pythium ultimum* obtained from various infected ornamental cuttings.

Control of the Disease. On Chrysanthemum. Preliminary experiments conducted in 1944 at Redwood City, California, on chrysanthemum cuttings in a clothhouse were supplemented by additional weekly tests in a clothhouse in the same locality during the months of February, March, and April, 1945. The coarse sand in one bench, previously used as the rooting medium, was treated by drenching with a 2 per cent solution of Formalin applied at the rate of ½ gallon per square foot of surface. A similar lot of sand in the second bench was untreated.

The basal half inch of each set of cuttings was treated with one of the following materials: (1) Ferbam, either alone or mixed with one-half its volume of Celite 505 (a diatomaceous earth); (2) Ziram; (3) Stim-Root (a commercial product containing 0.1 per cent indolebutyric acid, 0.25 per cent alphanaphthylacetic acid, and 1.65 per cent Spergon in 98 per cent talc); or (4) nothing. Dusting of each weekly allotment of cuttings of any one variety included 160 cuttings with Ferbam, 240 with Ferbam and Celite 505

mixture, 80 with Stim-Root, and 80 with Ziram. The controls consisted of 80 untreated cuttings. Excess dust on the surface of the cuttings was removed by gentle tapping on the edge of the container. Dusted and control cuttings were inserted in the sand and watered at frequent intervals. Additional moisture was provided by rainfall.

All cuttings to be dusted, as well as the controls used in each weekly test, were of the same variety. Since cuttings of any one variety of chrysanthemum were not available each week of the experiments, which continued for six consecutive weeks, several different commercial varieties were utilized, including White Frost, Pink Masaka, Yellow Pompon, and Yellow Tea.

Because of weather conditions, cuttings that were placed in the sand in February required 41 to 48 days for rooting, whereas those inserted in March required 28 to 35 days. Only an occasional cutting of the treated and control lots failed to root. Each weekly series of cuttings was removed from the sand for examination not less than 28 days after insertion.

There were no differences between comparable lots of cuttings rooted in Formalin-drenched and untreated sand. However, all dusted cuttings developed larger and more uniform root systems than did the undusted cuttings, regardless of variety, and were relatively free from basal rot. The data obtained are summarized in table 2. Control of the disease was effected by the three fungicidal dusts, but Ferbam and Stim-Root were somewhat more effective than Ziram.

TABLE 2. *Percentage of infection 28 to 48 days after dusting four varieties of chrysanthemum cuttings with various fungicides in six weekly tests for control of basal rot caused by Pythium ultimum.*

Treatment	Total cuttings dusted	Cuttings infected	Per cent infection
Ferbam	1920	45	2.3
Ferbam and Celite 505 mixture	2880	73	2.5
Stim-Root	960	20	2.1
Ziram	960	74	7.7
None	960	159	16.6

On Other Ornamentals. Because of favorable results obtained with the mixture of Ferbam and Celite 505 on chrysanthemum cuttings, further experiments were conducted in several nurseries. In these experiments cuttings of diverse ornamental plants were dusted with this fungicide mixture and placed in used sand for rooting. Untreated cuttings served as controls.

Ferbam mixed with Celite 505 was found to give excellent protection to the cuttings: it both inhibited disease and stimulated root formation. Roots were formed on dusted cuttings of various plants which had not previously

been rooted, or which rooted with great difficulty. Such stimulation had been observed by Tompkins (1944) in his earlier studies on the rooting of chrysanthemum cuttings. Basal rot developed in the controls, however, and root formation, if any, was poor.

Cuttings which were successfully rooted and were free from disease were of the following species: *Aucuba japonica* Thunb., *Bougainvillea* sp., *Buxus sempervirens* L., *Camellia japonica* L., *Chrysanthemum frutescens* L., *Daphne odora* Thunb., *Dianthus caryophyllus* L., *Diervilla* sp., *Erica* spp., *Euonymus japonica* L., *Euphorbia pulcherrima* Willd., *Fuchsia hybrida* Voss, *Gardenia jasminoides* Ellis, *Hedera helix* L., *Hydrangea paniculata* Sieb., var. *grandiflora* Sieb., *Lantana camara* L., *Ligustrum ovalifolium* Hassk., *Rhododendron indicum* Sweet, and *Veronica* sp.

Discussion. Basal rot of chrysanthemum cuttings in clothhouse propagating benches was of widespread occurrence in San Mateo and Santa Clara counties, California, during winters of high rainfall preceding 1945. Less disease was observed during the relatively dry winters of 1945 and 1946. A higher incidence occurred during 1947, 1948, and 1949 in those nurseries where old, infested sand was used and cuttings were not dusted. It has been the custom of many growers to use the same sand several consecutive seasons in propagating untreated cuttings, and this may account, in part at least, for the high incidence of disease.

An effective and inexpensive method of controlling the disease by dusting the cuttings with a mixture of Ferbam and Celite 505 and placing them in either clean or previously used sand in the propagating benches has been demonstrated. This procedure has been adopted as a standard practice by many chrysanthemum growers. During the propagating seasons of 1947, 1948, and 1949, it was observed that the Ferbam mixture continued to give excellent control of the disease on cuttings of all chrysanthemum varieties commonly grown.

The effectiveness of the Ferbam mixture in controlling basal rot of cuttings of certain other ornamental plants which have heretofore been difficult to root has also been demonstrated. This mixture is now in general use by nurserymen in the San Francisco Bay region.

SUMMARY

Basal rot of chrysanthemum cuttings is of general occurrence in clothhouse propagating benches in San Mateo and Santa Clara counties, California.

Symptoms of the disease consist of brownish-black, water-soaked lesions at or near the base of the cuttings. Infection spreads upward in the stems and downward into the roots, discoloring all tissues. Wilting may occur in

advanced stages of the disease. Stem tissues become soft and shrunken, and the cuttings collapse. Symptoms on cuttings of other ornamental plants included in these studies are similar.

Low air and soil temperatures and excessive soil moisture apparently predispose chrysanthemum cuttings to infection.

The causal organism of the disease affecting chrysanthemum has been identified as *Pythium ultimum* Trow, and its pathogenicity has been proved. *Pythium ultimum* was also isolated from the infected cuttings of 19 genera in 18 families of ornamental plants, but no infection tests were undertaken.

Basal rot of cuttings of chrysanthemum and other ornamental plants studied can be controlled by dusting their basal ends with a mixture of Ferbam and Celite 505. Cuttings may then be inserted into either clean or used sand in propagating benches.

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THE NATURAL AND SYNTHETIC QUINONES IN RELATION TO THE FUNCTIONS OF PLANTS[1]

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Most biologists are well acquainted with phenolic substances. They have long been recognized as natural constituents of plants. Such materials as anisole, cresols, thymol, carvacrol, guaiacol, veratol, eugenol, etc., are well known as natural substituted monohydroxy- and dihydroxy-benzene compounds. The naphthol and anthranol series are less well known as plant constituents.

Most of us have also at one time or other become acquainted with their physiological effects on microorganisms such as the bacteria and fungi. The best-known disinfectant, of course, is phenol or carbolic acid. The dihydric catechol and hydroquinone are less active but are known to be active against various microorganisms.

As early as 1930, Angell, Walker, and Link demonstrated that naturally-occurring phenolic compounds were fungicidally active against onion parasites. As a matter of fact, the resistance of red onions to the smudge fungus, *Colletotrichum circinans*, has been attributed to the presence of protocatechuic acid which is not to be found in susceptible white onions. In the course of studies on the chemistry of resistance of plants to Texas root-rot, Greathouse and Rigler (1940), tested 45 phenolic substances and found many of them to be fungistatic or fungicidal. In general they found that the monohydroxybenzene compounds were more active than dihydroxy- or trihydroxybenzenes. The introduction of an amino group ortho to the hydroxyl group in phenol enhanced activity while substitution in the meta or para position reduced the activity.

Many of the aromatic hydroxyl compounds may be oxidized to the quinone structure. Most biologists, however, are not so familiar with the characteristics of quinones, their natural occurrence, or their physiological effects on plant life. They are to be found, however, very abundantly in both the lower and higher forms of plant life. Their physiological significance is not too well understood. However, they undoubtedly serve as members of a strong redox system.

The materials of this system, 1,4,5-trihydroxynaphthalene and 5-hydroxy-1,4-naphthoquinone (Juglone), have been identified in the walnut.

[1] Material presented to the Torrey Botanical Club, February 7, 1950.

The trihydroxynaphthalene is common in the leaves and the quinone in the bark of roots and stem. The process by which the postulated interconversion occurs is not known.

In addition to regulating oxidation-reduction potentials the phenol-quinone system probably serves as a medium for building up more complex molecules; i.e., it facilitates substitution on the aromatic ring of hydroxyl, carboxyl, and similar groups; this eventually makes possible the formation of esters and aryl-alkyl ethers.

It is obvious that such reactions would be invaluable to the cell in building up more complex molecules as well as in stabilizing cell reactions and in regulating oxidative potentials. One might deduce that plant life would be just as seriously injured by disruption of the quinone balance as by interference with the phenolic member of the series which is known to be fatal to microorganisms. It is not surprising, therefore, in retrospect to know that quinones are powerful bacteriostats and fungitoxicants.

Interest in the quinones as fungicides was initiated in 1938 when W. P. ter Horst of the United States Rubber Co. selected chloranil (tetrachloro-para-benzoquinone) among other compounds for testing by E. C. Sharvelle and J. G. Horsfall of the New York Agricultural Experiment Station. The material proved to be exceptionally effective as a pea seed protectant (McNew, 1941), and gained a predominant position for this use under the trade name of Spergon. It also gave exceptional results on lima beans and other types of seeds (Cunningham and Sharvelle, 1940; McNew, 1942). In addition to being a very effective fungicide it also proved to be non-toxic to humans and animals when applied epidermally or ingested on treated seeds (McGavack *et al.*, 1943; McNew, 1948).

Further study by ter Horst and Felix (1943) revealed that 2,3-dichloro-1,4-naphthoquinone was much more potent than chloranil as a fungicide. In glass slide tests, it was about 20 times as effective as chloranil in preventing spore germination, and it protected tomato foliage from *Alternaria solani* at one-fifth the dosage. It was also more stable when exposed to light and weather conditions so it proved to be a superior foliage protectant.

In field trials, dichloronaphthoquinone (Phygon) gave almost perfect control of apple scab at 6 *ounces* in 100 gallons of spray and was effective against *Phytophthora infestans* on potato in spray mixtures containing 1 pound per 100 gallons. In order to secure equivalent control of the two diseases 8 pounds of sulfur or 12 pounds of copper sulfate-lime mixture would be required, respectively. It was more versatile than either sulfur or copper and controlled several fungous parasites (*Colletotrichum phomoides* on tomatoes and *Gymnosporangium juniperi-virginianae* and *Glomerella cingu-*

lata on apple) that were not amenable to control by standard fungicides. It did, however, interfere with pigmentation in some trials.

A rather complete survey of compounds containing the quinoid structure has been made. Although any generalization may have exceptions, the following relations held in general. Naphthoquinone and its substitution products are more fungitoxic than corresponding members of the benzoquinone series. The anthraquinones are relatively inactive except for 9,10-phenanthraquinone which is one of the more potent unsubstituted quinones. Halogenation usually makes them more active fungicidally but safens them for use on plants. In the benzoquinone series the halogens rate in the ascending order of effectiveness as activators: iodine, bromine and chlorine without tests on the fluorinated analogs.

As mentioned above, several hydroxyl, carboxyl and benzoic acid substituted quinones have been identified as natural constituents of the thallophytes and higher plants. Some of these materials have been tested as fungicides and found to be effective. In the naphthoquinone series, juglone (5-hydroxy-1,4-naphthoquinone) from walnuts has been described as a fungicide by Gries (1943), an observation confirmed by many tests made by the writer. Phthiocol (2-methyl-3-hydroxy-1,4-naphthoquinone) which may be isolated from the tubercle bacillus is fully as potent as chloranil against fungous spores. Vitamin K (2-methyl-3-phytyl-1,4-naphthoquinone) is another fungitoxic member of this series.

There has been no opportunity to test as fungicides members of the substituted benzoquinones isolated from fungi. Among these materials are compounds such as fumigatin, spinulosin, polyporic acid, muscarufin and phoenicin from species of *Aspergillus, Penicillium, Polyporus,* and *Amanita.* Insofar as known, these materials and the anthraquinones such as helminthosporin and cynodontin from *Helminthosporium,* boletol from *Boletus,* etc. have not been tested against other fungi.

No direct data are available on the nature of the mechanism for fungitoxicity in the quinones. Horsfall (1945) has suggested that the strong oxidation may account for their effects. This may be true since they probably would change the oxidation potentials of any fungous cell they penetrate. This certainly is not, however, the entire answer since E_o values and fungitoxicity of the series do not correlate too well. Parabenzoquinone, for example, with an E_o potential of .715 volts is less fungitoxic than 1.4-naphthoquinone with a value of .485 volts. Such comparisons, however, are largely superficial since we have no information on how readily the materials penetrate cells and enter into cellular reaction.

It is entirely possible that the quinones (and their phenolic analogs) operate by blocking one member of a mobile system that is necessary in

synthesizing essential cellular ingredients. The presence of analogous compounds in so many fungi would suggest such a hypothesis as a reasonable possibility. Sulfhydryl groups, such as are found in many enzymes, are known to be capable of forming addition products with quinones and might be inactivated by this mechanism. Any of these three possibilities exist as strong probable explanations for the effect of quinones on fungi, but direct data have not yet been presented.

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BULLETIN OF THE TORREY BOTANICAL CLUB
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A GIANT NEW CODIUM FROM PACIFIC BAJA CALIFORNIA

E. YALE DAWSON

One of the most remarkable algal discoveries resulting from the writer's current investigations of the marine flora of Baja California, Mexico is a gigantic new *Codium*. This plant is without question the largest member of the genus on record, and in all probability represents the world's largest coenocyte. The specimen illustrated in figure 1 is no less than 25 feet (74 dm.) long, one unbranched segment alone measuring 18 feet in length. The habitat of the plant in quiet, inner San Quintin Bay is remarkably suited to the development of large size in such a soft, fragile coenocyte, for the tidal flow is extremely gentle, and wave action is virtually nil. The longest plants grow on stones in and along the narrow, inner channel through which the tide moves more briskly and with which the plants gently stream back and forth. Along the margins of the lagoon, however, one encounters masses of detached and broken, but still living plants, sometimes piled up at low tide to a depth of 6–10 inches.

Heretofore, the largest *Codium* mentioned in the literature is *C. elongatum* Agardh which is said (Børgesen, 1925, Marine Algae of the Canary Islands, pp. 95–96) to reach a length of 6 feet 6 inches. So far as the writer is aware, no other *Codium* is known to have such extremely long internodes interspersed with broad, complanate portions as the present new plant.

Codium magnum sp. nov. may formally be described as follows: Thallis 10–74 dm. longis, ad basem semel vel bis dichotomis dein distanter dichotome ramosis, ramis intervallo magis quam 10 dm. longo saepius separatis, partis inferis pro more compressis, 1.5–2.0 cm. latis, superis saepius cylindricis, 12–15 mm. diametro, bene ad dichotomias applanatis expansisque saepius in partes laminarioideas 40 cm. longas, 10–20 cm. latas evadentibus; utriculis 250–700 μ diametro, 1600–2500 μ longis, subcylindricis ad clavatis, parietibus terminalibus parum inerassatis; gametangiis 290–325 μ longis.

Thallis saxicolous, 10–70 decimeters long, soft, flabby, attached by a short, irregular, stipe-like base, once or twice forked near the base and then distantly dichotomously branched, the intervals often exceeding 10 decimeters, the segments in heavier, lower parts mostly compressed, 1.5–2.0 cm. broad, those of upper parts mainly cylindrical, 12–15 mm. in diameter, prominently flattened and expanded at the forks and often forming laminarioid parts 40 cm. long and 10–20 cm. wide; utricles 250–700 μ in diameter, 1600–2500 μ long, subcylindric to clavate, the ends rounded or almost flat on

top, the end-wall unthickened, or thickened to 20 μ; gametangia produced 400–500 μ from the tips, cylindrico-conical, 290–325 μ long; hairs not observed.

FIG. 1. A photograph of the type specimen as it appeared when in the fresh condition.

TYPE: Dawson 8714, attached to stones along the margins of the innermost lagoon of Bahía San Quintin, Baja California, Mexico, and forming detached masses on the mudflats, December 31, 1949. (Allan Hancock Foundation Herbarium 49589, sheets 1–4.)

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INDUCED VASCULAR DIFFERENTIATION[1]

E. R. WITKUS AND C. A. BERGER

For many years Sinnott and his collaborators have studied cellular differentiation in relation to the problem of morphogenesis. In 1944 and 1945 together with Bloch he published an account of the cellular and intercellular changes accompanying the regeneration of vascular tissue after wounding. Earlier investigators, Vöchting (1892), Simon (1908), Freundlich (1909) and Kaan Albest (1934), had shown that differentiation of vascular tissue could be induced by wounding. Sinnott and Bloch studied, among other aspects, the changes induced in individual cells and the secondary developmental pattern involved in the regeneration and induced by the wounding.

In the course of some experiments performed in this laboratory on the cytological effects of combined treatments with naphthalene acetic acid and colchicine (Berger 1946) it was found that a certain treatment resulted in the formation of large polyploid cells whose walls assumed the characteristics of scalariform vessels while the cells showed considerable independence of any secondary pattern and an apparently complete divorce from any vascular function. To understand these results it is necessary to keep in mind the different cytological effects of the two substances used in the treatments.

Effects of naphthalene acetic acid. This substance has little or no effect on the promeristem and the primary meristem. It affects differentiated cells, especially those of the pericycle and cortex, and stimulates them to divide. It has been shown (Berger & Witkus 1948) that naphthalene acetic acid does not induce polyploidy but reveals its presence by inducing the polyploid cells to divide. There is a lag of about twenty-four hours between the beginning of the naphthalene acetic acid treatment and the onset of the stimulated divisions. In the pericycle cells the lag period is shorter, about twelve hours, and the stimulating effect is of longer duration than in cortical cells.

Effects of colchicine. Colchicine affects all cells in division whether they be meristematic or in differentiated tissues. It induces polyploidy by inhibiting the formation of a spindle. Colchicine does not affect cells in the resting condition.

[1] This investigation was supported in part by a research grant from the National Cancer Institute, of the National Institutes of Health, Public Health Service.

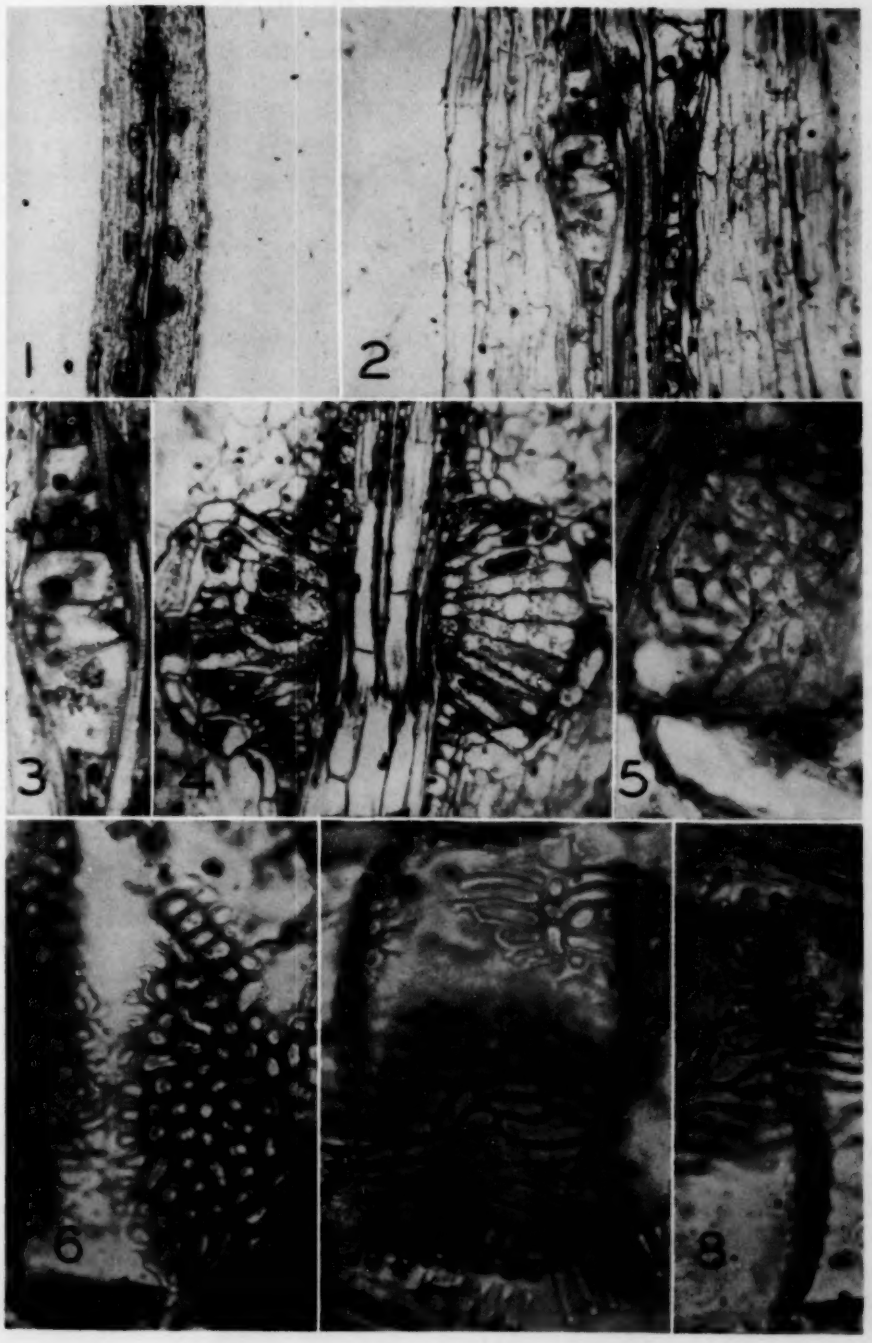
Experimental treatment. The particular treatment which resulted in the induced vascular differentiation was as follows. Bulbs of *Allium cepa* with young roots were immersed in a .0002% solution of naphthalene acetic acid for four hours. They were then placed in tap water for a twenty-four hour recovery period after which they were placed in a .25% solution of colchicine for twelve hours. They were then placed in tap water and cytological preparations were made at intervals during a recovery period of 264 hours duration.

Observations and results. As a result of the four hour treatment with naphthalene acetic acid dividing cells of the meristem complete their division and then remain in the resting stage for about twenty-four hours. Cortical cells which would normally not be in division are stimulated to divide. Although the smaller of these cells show the diploid number of chromosomes most of the cortical cells are large and have the tetraploid number. These cells divide only once under this treatment. The peculiar characteristics of these polyploid divisions have been described and illustrated in a previous publication (Berger & Witkus 1948). The cells of the pericycle are most strongly affected by the naphthalene acetic acid and begin to divide about twelve hours after the beginning of the treatment forming numerous young primordia of lateral roots (fig. 1). The roots formed at the base of an Allium bulb are adventitious roots and do not normally give rise to lateral roots in untreated material.

Twenty-four hours after the beginning of the treatment the cortical cells have completed their lag period and are ready to divide while many of the pericycle cells are already in division. The roots are then subjected to colchicine for twelve hours.

At the end of the colchicine treatment all the cells in division show the c-mitotic characteristics. Some of the large differentiated cortical cells undergo c-mitosis and show that they are tetraploid. These cells undergo only one division. Cells of the meristem undergo repeated c-mitoses and many become polyploid. Eventually, however, the diploid meristematic cells and divisions predominate and the growing root tip is diploid. Dividing cells in the pericycle, i.e. young lateral root primordia, undergo successive c-mitoses and become highly polyploid (figs. 2 and 4). About 200 hours after the end of the colchicine treatment the c-mitoses cease and the greatly enlarged cells of the root primordia return to the resting stage, each having

FIGS. 1–8. Photomicrographs of roots of *Allium cepa*. FIG. 1. Induced primordia of lateral roots. ×12. FIG. 2. Induced young lateral root primordium. ×125. FIG. 3. Same primordium showing wall thickenings. ×200. FIG. 4. Older induced lateral root primordium, showing polyploid cells in c-mitosis. ×150. FIG. 5. Network of cytoplasmic strands. ×750. FIGS. 6 & 7. Induced scalariform wall thickenings. ×750. FIG. 8. Matching of ridges in adjacent cells. ×750.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one or more irregular lobulated nuclei. Frequently these cells make an aborted attempt at cell plate formation which is usually never completed.

From 200 to 264 hours after the colchicine treatment these cells begin to take on the characteristics of scalariform vessels (fig. 3). They do not, however, assume the shape of vessels. The process is as follows. The walls begin to thicken, at first uniformly. As described by earlier observers the cytoplasm collects in a network or series of strands around the cell wall (fig. 5). Further thickening of the walls then takes place (figs. 6 and 7), apparently corresponding in position to the underlying strands of cytoplasm. The wall thickenings of adjacent cells frequently correspond in position (fig. 8). The nucleus is absorbed and disappears together with the cytoplasm. Such abnormally enlarged root primordia do not undergo further growth or differentiation but remain as a tumor buried within the main root. At times they remain covered by the unruptured endodermis. The cells which have acquired the characteristics of scalariform vessels do not connect with the vascular system of the root and apparently never function as vessels.

The effects just described occur only in very young primordia consisting of not more than one or two layers of cells (fig. 4) and before the differentiation into dermatogen, periblem and plerome takes place. In older primordia or in the tips of main roots, naphthalene acetic acid has no effect on the meristematic cells and the treatment here described would result only in a colchicine effect, causing polyploidy in dividing cells; after treatment the diploid cells would divide more rapidly than the tetraploids and all subsequently formed parts of the root would be diploid.

The stimulating effect of naphthalene acetic acid on the cells of the pericycle persists after the colchicine effect has ended and functional diploid lateral roots are later formed.

Discussion. The cells of the pericycle are superficially very similar to those of the promeristem yet the latter are unaffected by naphthalene acetic acid while the former are more strongly affected than any other cells in the root. It must be concluded that these two types of cells are very different physiologically.

In both the study of Sinnott and Bloch and the work of the earlier investigators the tissue involved was functional vascular tissue. In the present report the same type of cellular differentiation was induced in cells which apparently never function as vascular tissue. In this case since differentiation is separated from function it may be concluded that function does not play a causal role in this differentiation. Except for the matching of wall thickenings in adjacent cells there is little evidence in this material for a secondary developmental pattern. On this point also the cells here

described resemble tumor cells in their apparent independence of any regulatory pattern. What has been regarded in this paper as a twenty-four hour lag period in the case of the cortical cells may also be explained by supposing that a twenty-four hour period of stimulation is necessary to induce these more highly differentiated cells to divide.

SUMMARY

1. Roots of *Allium cepa* treated with naphthalene acetic acid (.0002% for four hours) give rise, after 12 hours recovery in tap water, to many young primordia of lateral roots.

2. If treated with colchicine (.25% for 24 hours) at this stage, the cells of the young lateral root primordia increase greatly in size and become highly polyploid.

3. Growth of the lateral root primordia ceases and the walls of the greatly enlarged cells take on the characteristics of scalariform vessels. These nests of abnormally differentiated cells never give rise to lateral roots but form small tumors buried within the tissue of the original root.

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BULLETIN OF THE TORREY BOTANICAL CLUB

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TORREYA

Homer Doliver House, 1878 to 1949. Born near Oneida, New York, July 21, 1878, Homer D. House spent most of his life in the State. He received his B.S. at Syracuse in 1902 and the A.M. at Columbia, 1904, where he also assisted. While working for his doctorate he was an Aide at N. Y. Botanical Garden and had temporary positions at Rutgers, the U. S. National Museum, and the U. S. Department of Agriculture. He was Professor of Botany and Bacteriology at Clemson College, S. C., 1906 to 1907. The Ph.D. in botany was conferred by Columbia in 1908. He married Erma N. H. Hotaling December 21, 1908.

There followed a period of five years that was very stimulating and instructive to Dr. House. He was appointed Lecturer in Botany and Associate Director to Dr. C. Alvin Schenk who founded Biltmore Forest School, Asheville, N. C. There he taught dendrology, forest geography, and climatology and was associated with Gifford Pinchot, Joseph S. Illick, and other early leaders in forestry. It was the custom of the School to travel widely, including a tour of European forests, as part of the regular training. Dr. House wrote ". . . no one who has ever visited the region of the Black Forest fails to look back upon that visit as one of the milestones upon life's journey." He published his observations and interpretations as "Certain Features of German Forestry" (N. Y. State Museum Bull. 176, 1915).

Dr. House moved to Albany in 1913, where he was to spend the rest of his life in technical taxonomy. He was Assistant State Botanist in the New York State Museum for a year and during this time responsibility was rapidly being transferred from Dr. Charles Horton Peck. In 1914 Dr. House was appointed State Botanist and retained the position until retirement November 30, 1948. After official retirement he continued to come to the office almost daily, doing routine work and revising his "Annotated List."

From 1913 to 1924 Dr. House reorganized and improved the herbarium and gathered much detail on the flora of New York. Rather long "Reports" of the State Botanist were issued from 1913 to 1917. They contained information of mainly temporary interest. However, they recorded numerous additions, corrections, and other "raw material" from which comprehensive works are built. For instance, the 1917 Report included 27 full page plates of photographs and microscopic drawings of fungi, many being taken from type specimens. Certainly Dr. Peck's work was carried on by an avid disciple; this was in addition to development of Dr. House's own broad interests. Consequently, the program covered fungi, ferns, and flowering plants from a variety of locations. This productive period culminated in the large "Annotated List of the Ferns and Flowering Plants of New York State," published 1924.

Many consider Dr. House's greatest contribution to be the beautifully illustrated two volume set: "Wild Flowers of New York." An experimental printing of four plates was made in the Report of 1915. The full text and 264 quarto plates printed in a four-color process was published in 1918 as Memoir 15 of the State Museum. The term "wild flowers" referred mainly to the conspicuous-flowered herbs. (The books have long been out of print but the unbound plates may still be purchased from the Museum.) This work was reprinted in one volume, with minor changes and omissions, as "Wild Flowers" by the Macmillan Co., 1934. Dr. House's beautiful natural color plates had the effect of setting the standard of excellence for many flower books that were to follow.

Although Dr. House spent most of his time in the field or in the herbarium he was fully aware of the need for mastery of the literature. His first "Bibliography of the Botany of New York State" appeared in 1916. A more complete edition, covering 1751 to 1940, was issued in two parts in 1942. The references were arranged by geographic

regions and counties and were indexed by species, localities, subjects, and authors. Nearly a complete bibliography of Dr. House's works is accessible in this publication. His last paper was printed in the N. Y. State Conservationist, April–May number, 1948.

As sometimes happens, recognition nearly came late. However, the Botany Seminar, an informal group that has been meeting in the New York Capitol district for two years, prepared a memorial parchment scroll. At length a representative list of signatures was collected. Dr. R. A. Dobbins, Albany Pharmacy College, and Paul C. Lemon, representing the Seminar, waited upon Dr. House in his office and presented the scroll December 19, 1949. Two days later Dr. House was suddenly stricken while walking across his lawn. He is survived by Mrs. Erma House, who shared his interest in flowers and birds.

Dr. House was a member of numerous learned societies of international importance: Torrey Botanical Club, Botanical Society of America, Ecological Society of America, Botanical Society of Czechoslovak, American Association for Advancement of Science, Society of American Foresters, American Fern Society, Rochester Academy of Science, and the New York Academy of Science.—PAUL C. LEMON, N. Y. State College for Teachers, Albany, New York

FIELD TRIP REPORTS

April 2, 1950. Alden, N. Y. Mosses, hepatics, and lichens were the major attraction, with the usual species displayed. No additions were reported for the area list. Attendance 14. Leader G. G. Nearing.

April 9. Orange, N. J. The day was extremely cold, average temperature thirty nine degrees and never above the middle forties. The fact that we have had temperatures around ten degrees below normal for several days certainly affected the plant life. Spring beauties were just beginning to come out, as were common and mouse-ear chickweeds; golden saxifrage along Canoe Brook was almost in bloom. Coltsfoot was conspicuous around the edges of the South Mountain Reservation, and red maple, elm, and willow were everywhere in bloom. Alders were covered with catkins along a branch of Canoe Brook and we found a small specimen of *Populus grandidentata* with catkins fully out. Most conspicuous thing in the forest was the budding spice bush. Only the more common liverworts were found. It was too cold and windy for much bird life: a number of kildeer in the farm land at Livingston, plus robins, red wings, song sparrows, chickadees, phoebes, and juncos. Attendance 8. Leader, Miriam Studley.

April 16. Farmingdale, N. J. At the headwaters of the Manasquan, Mr. Frazee told us the story of the marl pits, and how the marl was used as fertilizer, in fact in early days it was quite a busy section until someone discovered marl was really useless. Along the Manasquan we found *Caltha palustris, Viola cucullata, Sanguinaria canadensis* and *Anemonella thalictroides;* we only found a few of each of these, whereas in previous years, one could not walk without tramping on some small flower. Then on past the Brisbane Preventorium, and into the Park where we all enjoyed a hearty lunch, and though our leader forgot the "watermelon" still we survived. After lunch we walked about a mile along the banks of the Mingmahone. In previous years these banks were covered with *Dicentra cucullaria,* however again owing to cold weather, we found only small leaves of Dicentra showing, but we did find flowers of the *Erythronium americanum.* We returned to the cars and drove to the deserted village of Allaire, where Mr. Frazee related the history of its past to us, and one could easily imagine Allaire at its peak, as we listened. Attendance 13. Leader, Vernon L. Frazee.

April 23. Silver Lake, White Plains, N. Y. Our trip to White Plains was wet as it rained all day. On one of the back trails at Silver Lake we found literally acres of

Dicentra cucullaria and *Sanguinaria canadensis* in full bloom. The wild hydrangea bush is still in good condition, (*Hydrangea arborescens*). There were very few herbaceous plants and a few shrubs in bloom. It seemed more like March than April. Attendance 6. Leader, Farida A. Wiley.

April 23. Andover, N. J. Limestone inhabiting plants of all sorts were examined in the vicinity of Andover and Springdale. No new species for the area list were reported. Continued rain. Attendance 11. Leader, G. G. Nearing.

April 29, Lakehurst, N. J. The backward spring season was quite apparent in the Pine Barrens on our trip to Lakehurst, Collier's Mills and Forked River. Pyxie moss was at the height of its bloom and quite breath-taking in its beauty. Several maroon-colored leafy patches of it having a profusion of delicate white flowers which would have been a photographer's delight. Golden club and trailing arbutus were abundant, but only a few stands of bird-foot violet were observed. At Collier's Mills the field pansy (*Viola rafinesquii*) was in full array. Sand myrtle was tightly budded and indicated that it would not be on display for another week or more. Torrey trips to Forked River in recent years have been too late to observe the blooming of the southern twayblade (*Listera australis*). We therefore visited the station at the close of the trip to see if it would be the proper season. We found about twenty plants in bud which probably would be in bloom about May 5–10th, but which in a normal season would be in flower about April 25–30th. The station is in excellent condition.

The lateness of the season (botanically) provided us with an ornithological highlight not expected. Mrs. Camp of Toms River brought us to her home where we were thrilled by the sight of evening grosbeaks at her feeding station. Both males and females were observed at a range of one to three feet at times. A list of about 30 species of birds was tabulated, over half of which were observed at Mrs. Camp's highly successful feeding station. Those present agreed that the grosbeaks stole the show from the flora of the day. Attendance 6. Leader, David Fables.

April 30. Cheesequake State Park, N. J. A newly mimeographed list of plants soon became obsolete as nine species were added during the trip. The list now stands: trees 42, shrubs 69, herbaceous 388, ferns and allies 19. Total, 518 vascular plants. Most impressive finds were bloodroot, and the early woods-buttercup with its tapering roots like miniature carrots. For the record, it rained. Attendance 14. Leader, Louis E. Hand.

NOTES

The first issue has just appeared of the *Journal of Experimental Botany*, published by the Clarendon Press in Oxford, and edited by T. A. Bennet-Clark. It contains, among other articles, "Further studies of acid metabolism of *Aspergillus niger*," "The path of carbon in photosynthesis," "Studies of stomatal behaviour," and "The effects of sugar and potassium on extension growth in the root." There are to be three parts in each annual volume.

A new periodical named *Oikos* is to be devoted to ecology. According to the announcement, "it is to be the forum of Scandinavian ecologists, although in special cases scientists in other countries are to be invited to contribute." It will appear twice a year, is published by Einar Munksgaard in Copenhagen and edited by H. O. Backlund. —H. W. R.

BOOK REVIEWS

Trodden Glory. The Story of the California Poppy. By Cameron Rogers. 130 pages, 3 plates. Wallace Hebberd, Santa Barbara, 1949. $2.50.

This journalistic ''scamper'' regales the ''frolic flower,'' *Eschscholtzia californica*[1] of the botanist with stories about how this ''inexpressibly debonair wilding,'' this ''sea-plain and foothill troubadour,'' came to be called Eschscholtzia after a Baltic Russian surgeon by the poet, story-teller and botanist Adelbert von Chamisso. The author of *The Magnificent Idler—the Story of Walt Whitman,* and kinsman of Hubert Howe Bancroft, the historian, carries on a ''friendly raillery'' about the poppy, and all the figures in California history who baptized it, carried its seeds to Europe, and helped to make its homeland famous. Chamisso, Eschscholtz, and Douglas,—Prussian, Balt, and Scot—, are the foci of the story. Each are sketched in informal prose, sometimes nauseous, and each is illustrated by a portrait lifted from previously published sources (botanical journal *Madroño,* etc.) without acknowledgement. There are bits of smart writing: ''Much as a gadfly browsing on the withers of a lion'' did Madame de Stael irritate Napoleon. La Perouse's visit to Monterey is noted as ''stop-press news,'' and Capt. Vancouver is described as ''by no means a 'Bread-fruit Bligh' he was a cat of the stripe.'' Rogers is particularly fond of sea-otters. They are for him a kind of ''trodden glory.'' The sea-otter's ''fatal tragedy was that it skipped, swam, dove and gambolled in a fur coat prized above rubies in Macao and Canton.'' Another Rogers would have been engaged to learn that the otter used *Nereocystis luetkeana,*[2] a giant kelp called in fact ''sea-otter's cabbage'' by the seamen, as birth mats for its young. Rogers would call them carrier bases. *Facetiae* is a time-honored limbo in booksellers' catalogs. Rogers' skit meets all the prerequisites: imprint of unusual geographic origin (Santa Barbara), small edition, and ''multiplex author'' of collectable character. Be sure to preserve the attractive undustable dust jacket!—JOSEPH EWAN.

Minimum Areas for Different Vegetations, Their Determination from Species-area Curves. By Arthur G. Vestal. VI + 129 pages; *fig. 1–6; tables 1–26;* Illinois Biological Monographs vol. 20, no. 3; University of Illinois Press, Urbana. 1949. cloth $3.00, paper $2.00.

Intensive study in two old-growth mixed forests in Illinois led to the recognition of three sizes of reference areas each showing a certain connection between numbers of species and degree of informativeness. It is explained that a reference area is ''one yielding a definable degree of information concerning the stand or type in which it lies.'' The three reference areas established were the ''fair-sized stand,'' the ''minimum area,'' and the ''smallest representative area.'' The smallest representative area is the area with half as many species as the fair-sized stand and one fiftieth its area. The ''minimum area'' is defined as ''an area five times the small one.'' ''—it clearly identifies the type of forest; it provides a minimum statement of composition with approximate ranking of species as to number of trees and as to some measure of bulk or of ground space occupied.'' The minimum area is ''too small to give a dependable picture of diameter-distribution (form of the stand).'' It is left for the reader to assume that this is a characteristic of the fair-sized stand. The latter is defined as an area 50 × the smallest representative area and 10 × the minimum area.

With these reference areas thus established and defined in terms of ratios of area and number of species, the author then locates them on species-area curves. His curves, constructed on semi-log paper are concave in their lower or small-area section and convex in their upper section. The smallest representative area and the fair-sized stand are exact points on this S-curve. With the exception of a pair of obviously inadequate points at the extreme lower end of the curve, there is only one pair of points where one area is 50 × the other with 2 × the number of species. These establish the smallest rep-

[1] There is no reason to perpetuate an obvious typographic error by using the form ''Eschscholzia.'' International Rules of Botanical Nomenclature permit the correction of such spellings.

[2] For a sober account of Fyedor Petrovich Lütke, and other Russian figures mentioned by Rogers, see N. Nozikov's *Russian voyages round the world* (London, n.d., *circa* 1942).

resentative area and the fair-sized stand. The minimum area can readily be found since it is the area 5 × the smallest representative area. The two points can readily be located by trial and error method when species-area curves have been constructed.

Having thus erected a platform of definition and developed a method of procedure, the author proceeds to construct species-area curves for quite a number of different vegetation types of the world. These vary all the way from tropical rain forests to lichen communities. In the process he draws upon data obtained by a number of different workers. Obviously such data were by no means uniform so in order to have his curves comparable he had to develop means of conversion of the data to serve as a basis for the curves. Among the 240 species-area curves for which areas and number of species were determined many were constructed with a far less solid basis of data than others due in part to such necessary conversions. The degree of dependability thus varies considerably.

A large part of the book is taken up with tables presenting minimum areas, number of species in the minimum areas, and number of species on the smallest representative areas. In each case the degree of dependability of the data as far as it applies to the species-area curve is given. The author believes that the reference areas determined according to this method are comparable for the different types of vegetation. Thus a mesophytic type of prairie border forest in Illinois has a minimum area of 16,249 square meters with 18.3 species compared with 2,743 square meters and 9.2 species of a Norway pine forest in Wisconsin or 28,834 square meters and 57.0 species for a virgin forest in Ceylon.

The book is a valuable contribution to statistical ecology. It will become a standard reference point whenever the problem of relationship of species to area is involved. To the extent that workers are ready to accept the author's proposed platform of definition as a starting point they will find the book a valuable reference because after the species-area curve is constructed the procedures are completely objective. The dependability of the curve of course varies with the adequacy of the data. The procedure makes it possible to compare diverse stands directly and simply. It allows one to know the extent of sampling necessary to attain a certain defined "minimum area." As far as previous studies are concerned it is of especial interest to note that the minimal area which has usually been adopted in many cases is no larger than the author's smallest representative area. This, the author says, is "adequate for many purposes, since it almost always includes all the more abundant and generally distributed species of a stand."

The latter part of the book deals with a review of the magnitude and range of reference areas for different types, the geometry of the S-curves, factors influencing the size of the reference areas, and implications of certain results. Hypotheses to explain species-area curves are also discussed.

The volume consists of 129 pages with 6 figures and 26 numbered tables. There are 122 citations listed in the bibliography, a large proportion representing the source material from which the species-area curves were constructed.—MURRAY F. BUELL, RUTGERS, THE STATE UNIVERSITY OF NEW JERSEY

Vilda Växter i Norden: Mossor, Lavar, Svampar, Alger. (Native Plants of Scandinavia: Bryophytes, Lichens, Fungi, Algae.) By John Axel Nannfeldt and G. Einar Du Rietz. xlviii + 433 pages; pl. 1–212 (photographs in natural color), figs. 1–361. Bokförlaget Natur och Kultur, Torsgatan 31, Stockholm, Sweden (Kr. 80.): Chronica Botanica Co., Waltham, Mass. $17.50. 1945.

When the series, "Vilda Växter i Norden"[1] was planned, it was not intended that the lower cryptogamic plants should be included. As the result of popular demand, however, this volume has now been prepared by two of the most prominent cryptogamic botanists in Sweden to cover the bryophytes, the lichens, the fungi, and the algae.

A landmark in twentieth century botanical literature, this book takes us back to the first half of the nineteenth century, when hand-colored plates of high quality were not uncommon in treatises on plants. It is no exaggeration to say that, both in number and in quality, the plates in natural color illustrating this volume are the finest to appear in a serious work on cryptogams during the present century. These 212 plates of photographs of living plants in their natural habitat show the habit and aspect of each species with exceptional fidelity, and therefore provide an excellent means by which both amateur and professional botanists will be enabled to recognize the commoner cryptogamic plants in the field without effort. The original photographs in color must have been truly magnificent in order to make possible the production of printed illustrations of such consistently high quality. This volume is also abundantly illustrated throughout the text with drawings, photographs and maps. The distribution of text figures and colored plates among the different groups of cryptograms is as follows: Hepaticae, 5 plates, 7 figs.; Musci, 34 plates, 41 figs.; Lichens, 59 plates, 95 figs.; Ascomycetes, 7 plates, 18 figs.; Basidiomycetes, 71 plates, 71 figs.; Chlorophyceae, 4 plates, 42 figs.; Phaeophyceae, 14 plates, 29 figs.; Rhodophyceae, 17 plates, 18 figs.; and Cyanophyceae, 1 plate, 8 figs.

Emphasis is placed in the text on those species that are illustrated with colored plates, and the headings are numbered to correlate them with the plates. Although the number of species treated in the text may therefore seem to be small, at first sight, it will soon be found that many paragraphs ostensibly devoted to single species are really brief reviews of several species. The descriptions are relatively non-technical and include helpful remarks on those characters most useful in separating closely related species. The abundant ecological notes are reinforced in the text with excellent photographs showing habitats and associations of species.

The combination of superb illustrations, beautiful binding, (one-half leather), and excellent paper and typography make this book an outstanding example of modern craftsmanship in book manufacture, for which the authors and publisher are to be congratulated. It is only to be regretted that this great work was not also published in English, since most of the species and genera described and illustrated occur in northern North America. Nevertheless, this volume will be of real utility to American cryptogamic botanists who do not read Swedish, because of the extraordinarily lifelike and beautifully reproduced photographs.—WILLIAM C. STEERE.

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INDEX TO AMERICAN BOTANICAL LITERATURE

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LAZELLA SCHWARTEN

WITH THE COLLABORATION OF THE EDITOR OF THE TAXONOMIC INDEX

TAXONOMY, PHYLOGENY AND FLORISTICS

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